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MEMBERSHIP.

Terms and Privileges.

Members of the Institute shall consist of those engaged or interested in scientific pursuits or in the application of science in the mechanic and industrial arts. Members shall be classed as follows: Honorary and Corresponding, Endowment, Life, Contributing, Resident, Non-resident, Holders of Second Class stock.

Honorary and Corresponding members shall be nominated by the Board of Managers and shall require for their election four-fifths of the votes of the members present at any stated meeting of the Institute at which their nomination may be acted upon. They shall not be entitled to vote or hold office. All other members shall be elected by the Board of Managers.

Endowment members shall consist of persons, firms, corporations or associations who shall make an endowment payment of Five Thousand Dollars ($5000) to the Institute, and who, upon acceptance thereof by the Board of Managers, shall thereafter have the privilege of nominating annually to the Board of Managers for election (subject to its discretion as to any particular nominee) as Resident members of the Institute for its then current year without payment of dues that number of persons, to be determined from time to time by the Board of Managers, whose annual dues if they were paying annual Resident Membership dues would approximately equal but not exceed the then current income from such endowment payments. Such Endowment Memberships shall be perpetual, and shall be transferable by the holders thereof by will or otherwise: Provided, however, that the Board of Managers at any time may refund Five Thousand Dollars ($5000) to the then holders of any such membership, and annul and terminate that membership.

Resident Life members, whose memberships shall not be transferable, shall pay the sum of Three Hundred Dollars ($300) in any one year. Non-resident Life members shall be those who reside permanently at a distance of not less than twenty-five miles from Philadelphia and shall pay the sum of One Hundred Dollars ($100) in any one year.

Contributing members shall consist of firms, corporations, associations or individuals who shall pay annually the sum of Three Hundred Dollars ($300). A Contributing member shall have the privilege of nominating nineteen persons to the Board of Managers for election as Resident members for the year then current, subject to the discretion of the Board as to any particular nominee, and members thus elected shall pay no dues.

Resident members shall pay annual dues of Fifteen Dollars ($15).

Second Class Stock may be purchased for Ten Dollars per share and holders are entitled to all the privileges of membership so long as they make the annual payment of Twelve Dollars.

Non-resident members shall be those who reside permanently at a distance of not less than twenty-five miles from Philadelphia. They shall pay an entrance fee of Five Dollars and annual dues of Five Dollars. Transfers of membership from the Resident to Non-resident class may be granted by the Board of Managers at its discretion in cases of temporary absence of members from the city for a period of not less than one year.

Student members shall be over sixteen and under twenty-two years of age. They shall pay annual dues of Three Dollars if they do not receive the JOURNAL of the Institute, and Six Dollars if they do receive the JOURNAL.

Resignations *must be made in writing, and dues must be paid to the date of resignation.*

Membership Badges.—Pin or button form, may be purchased from the Controller for One Dollar.

For further information and membership application blanks address the SECRETARY OF THE INSTITUTE.

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The following awards are made by The Franklin Institute:

The Franklin Medal (Gold Medal).—This medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

The Elliott Cresson Medal (Gold Medal).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (Gold Medal).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles.

The George R. Henderson Medal (Gold Medal).—This medal is to be awarded for meritorious inventions or discoveries in the field of railway engineering.

The John Price Wetherill Medal (Silver Medal).—This medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

The Edward Longstreth Medal (Silver Medal).—This medal is awarded for inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance.

The Louis E. Levy Medal (Gold Medal).—This medal is awarded to the author of a paper of especial merit, published in the JOURNAL OF THE FRANKLIN INSTITUTE, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

The Walton Clark Medal (Gold Medal).—This medal is awarded to the "author of the most notable advance in knowledge or improvement in apparatus, or in method concerning the science or the art of gas manufacture or distribution or utilization in the production of illumination, or of heat, or of power."

The Certificate of Merit.—A Certificate of Merit is awarded to persons adjudged worthy thereof for meritorious inventions, discoveries or improvements in physical processes or devices.

The Boyden Premium.—Uriah A. Boyden, Esq., of Boston, Mass., has deposited with The Franklin Institute the sum of one thousand dollars, to be awarded as premium to "any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity."

For further information relating to these awards apply to the Secretary of the Institute.

Journal
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Vol. 210 JULY, 1930 No. 1

A MOMENTOUS HOUR AT PANAMA.*

BY

JOHN FRANK STEVENS, LL.D.

There has been published from time to time such a mass of information about the Panama Canal, a project which aroused much controversy a quarter of a century ago, that any reference to it after the lapse of years may seem to be quite superfluous; but as is often the case in human affairs, history does not always record events which have had a profound influence for good or evil upon the solution of the problems involved. The history of the planning and construction of the Panama Canal is no exception to such general rule.

The condition of affairs on the Isthmus during a part of the year 1905 can truly be described as desperate; by many well-wishers even it was regarded as hopeless. When the speaker arrived there in July of that year, he found not even the skeleton of a general organization. Supreme authority was vested in no one. The Sanitary Department was the only one having the semblance of a proper organization, and it was doing a limited amount of work under what would probably have proven a fatal handicap had it continued. The usual tropical diseases were prevalent, and that scourge of the white race, yellow fever, was taking its deadly toll daily. While the situation was in some degree psychologic, the danger was great, enough so that unless the disease was

* Presented at the Medal Meeting held Wednesday, May 21, 1930.

promptly checked and thereafter held under control, the success of the great enterprise would be jeopardized.

The tragic story of the French attempt to build a canal there was in many mouths, and predictions were freely made that the history of the Americans on the Isthmus would be a repetition of the De Lesseps failure. Under the then existing conditions it would not have been possible to have held the small force of clerical and skilled white labor which had been collected, much less to have induced thousands of other whites to have entered the service. Especially so in view of the pessimistic attitude which some of the American press had taken, and the exaggerated accounts which they were publishing as to living and health conditions on the Isthmus, some influential members openly advocating that the whole undertaking should be abandoned as affording no hope of a successful outcome.

At that time few of the general public knew anything of the so-called mosquito theory of the transmission of yellow fever, and they mostly regarded it as purely theoretical. Not so with the medical scientists who had successfully demonstrated it in Cuba, and of those scientists was Col. William C. Gorgas of the Medical Corps of the Army, who was the head of the Sanitary Department on the Isthmus. He was working intelligently with a small but efficient staff, but with an utter lack of coöperation on the part of his immediate superiors. He was one of the first officials that I met there, and from him I gained my real insight into the famous theory.

Of Colonel (later General) Gorgas, his work and supreme service to mankind, it is unnecessary to speak here. His memory is so deeply cherished, and his fame is so secure that no words of mine can add to either. Best of all, he was a kindly, sincere man, the highest type of gentleman, and I am proud to have known him, not only officially, but also as a warm friend.

The then Chairman of the Isthmian Canal Commission accompanied me on my first visit to the Isthmus, he remaining there but five days, as the situation did not appeal to him. At that time Colonel Gorgas was reporting to the Governor of the Canal Zone. Neither the Governor nor the Chairman

had the least faith in the efficacy of the mosquito theory, at least they so emphatically advised me at once, and their actions confirmed their words.

Quoting from a brochure of General Gorgas' life and activities, written by the President of the American College of Surgeons: "Finally, in June, 1905, the Governor and Chief Engineer (my predecessor), member of the executive committee of the Commission, united in a recommendation to the Secretary of War that the Chief Sanitary Officer (Colonel Gorgas) and those who believed with him in the mosquito theory should be relieved, and men with more practical views be appointed in their stead. They stated that the Sanitary authorities had visionary ideas with regard to the course of yellow fever, and no practical methods even of carrying them into effect."

The President declared his faith in the theory and directed that every possible support and assistance be extended to the Sanitary officials. Personally, I have no knowledge except from hearsay of the accuracy of these statements, although I believe them to be true. What I *do* know is that such directions were not carried out either in letter or spirit.

Quoting again from the same authority: "About this time Mr. John F. Stevens was appointed Chief Engineer of the Commission, and he recommended that the Sanitary Department should be made an independent bureau and report directly to himself. This enabled Colonel Gorgas to make known his needs directly to the highest authority, and there he was accorded loyal support. 'This', remarks Gorgas, 'was the highwater mark of Sanitary efficiency on the Isthmus, and more sanitation was done at this time than during any other period of the construction of the canal.'" Incidentally, I may here remark that on my recommendation some time afterward the President appointed Gorgas as a member of the Isthmian Canal Commission.

However, these results were not achieved without a sharp controversy, during which the Chief Engineer clashed sharply with the Chairman and the Governor. I had been very deeply impressed by my conferences with Colonel Gorgas as to the probable truth of the mosquito theory, as well as by his personality. I also felt well assured that no canal could be

built at Panama until the specter of yellow fever had been laid. There was no other promise of relief in sight than that of Gorgas and the mosquito theory, and there seemed to be but one course to follow.

On the occasion of a trip over the Panama Railroad, accompanied by the Chairman and the Governor, the sanitary work which was in progress, visible from the train, such as drainage of pools of water, applying oil where drainage was not practicable, fumigation of houses, etc., was pointed out to me in great detail by these officials, accompanied by constant ridicule, not only of Colonel Gorgas but also of the mosquito theory, some of these comments reflecting very severely upon the quality of the Colonel's mental equipment.

My attention was repeatedly called to the great waste of money and the utter futility of the whole procedure. It became very apparent that a serious situation existed, and I was in a quandary as to how it could be met, as I well knew that it must be, or a total collapse was inevitable. The climax came quickly.

The day before the Chairman sailed for the States he advised me that he and the Governor had decided that Colonel Gorgas must be gotten rid of (in his precise language, that he would "fire" him), and the mosquito theory, also. Some quick thinking and an important decision was needed on my part, which decision I proclaimed in rather heated language, not to be repeated here. At the close of my harangue, I said if there seemed to be the least likelihood of approval of his action being given by the President (which I did not believe possible) I should take the matter in person to Washington; and that if Colonel Gorgas were removed I should not come back to the Isthmus.

I asked him what he thought the reaction would be from the doubtful ones, and from the already unfriendly press, if it became known that the Commission had urged the abandonment of the mosquito theory and the disruption of the Sanitary Department, and stated that, furthermore, if after a hasty visit to the Isthmus the new Chief Engineer had, by his action, indicated his belief that the construction of the Canal was impossible, it would mean chaos, whatever attitude the President might take. If it did not kill the project it would

certainly delay it, and the end no man could foresee. He left for the States without further comment on the matter. If he urged his views in Washington (which I do not believe he did) I was never advised, and so the matter ended there, as it should.

I was seeking a way to stabilize the situation, for it was no time to be rocking the boat. Opportunity must be given for the Sanitary Department to prove its faith by its works, which I believed it could do.

It was not a question of Colonel Gorgas' business ability, but one of making the Isthmus a safe place for white people to live and work, and that quickly, regardless of whatever cost in mere money might be involved. Beyond doubt those officials were sincere in their opinions, but in my judgment they were wrong.

It was after this occurrence that Colonel Gorgas began to report to me, and from that time forward harmony prevailed. The Sanitary Department was furnished with everything it asked for as fast as it could be provided, and every other activity was made subordinate to its needs. Sanitary success soon became so apparent, coincident with the creation of a general organization, that carping criticism was practically stilled, for the first time since the American occupation of the Isthmus. Science had scored a wonderful triumph over a deadly foe to the human race.

Sanitation was fundamental and the success which the Sanitary Department achieved under Colonel Gorgas made the Panama Canal possible. When the result of its work became manifest, and when the lock type had been adopted, then the successful construction of the Canal was as well assured, early in 1906, as it was on that historic opening day in August, 1914, when the Steamship "Ancon" passed through it from ocean to ocean.

At this distance of time and space the episodes related may seem trivial. Only one who was on the ground, charged with tremendous responsibilities, can comprehend the magnitude of the issues at stake. A rejection of the mosquito theory at that juncture would probably have meant the indefinite postponement of the canal project.

I have said that I did not then deem it possible that

President Roosevelt would uphold the elimination of Colonel Gorgas, but an occurrence which took place some years later gave me food for thought. Sometime after Mr. Taft had become President, Colonel Roosevelt sent me an invitation to call upon him, which I did at the office of the *Outlook* magazine in New York. After some preliminary talk he told me that friction among officials on the Canal had reached such a point that changes would have to be made, and that he thought Colonel Gorgas would have to go. He said that he was well aware that I knew more of Gorgas and his work than any man, and asked if in my opinion he should be kept.

It is needless to repeat what I told him. It was emphatic and to the point, and I closed by saying that if Gorgas were removed it would be a stupid blunder. Colonel Roosevelt pounded the desk in his usual vehement manner and exclaimed, "That settles it, Gorgas stays." Which he did, through what influences one can only conjecture.

I have thought, since that time, that possibly it was just as well that the issue was not raised to a finality in July 1905. I had reason to know that the President then had great confidence in the Chairman, but the Status of the Chief Engineer in that respect had yet to be demonstrated. I did not have faith enough in the result to wish the matter put to a test.

In the year 1914, when Gorgas was Surgeon General, I received a letter from him, reading in part as follows:

"I have a very clear and grateful recollection of the support and friendship you always gave me on the Isthmus. I knew very well that you were the only one of the chief officials who believed in the sanitary work we were doing, and who was not taking active measures to oppose us. The fact is that you are the only one of the higher officials on the Isthmus who always supported the Sanitary Department, and I mean this to apply to the whole ten years, both before and after your time, so you can understand that our relations, yours and mine, stand out in my memory of the very trying ten years I spent on the Isthmus, as a green and pleasant oasis."

Only fragmentary accounts of these episodes have ever been related, and as now that every one of those officials who were directly concerned with them, President, Secretary of

War, Governor, General Gorgas—everyone excepting myself—has passed beyond the sphere of human activities, it seems fitting that while first-hand knowledge of the matters then at issue is yet available, it should become a part of the history of the construction of the Canal, for it is not believed that the full significance of these events has ever been appreciated.

Meteorites. A monograph on the composition and structure of meteorites was written by the late GEORGE P. MERRILL, who died suddenly on August 15, 1929, and has been published by the Smithsonian Institution (*U. S. Nat. Mus. Bull.* 149, 1930, 62 pages, frontispiece and 32 plates). Of the known chemical elements, 28 have been found in meteorites while the presence in them of 7 additional elements is in doubt. Of the minerals present in meteorites, 16 are also terrestrial, while 12 are rarely if ever terrestrial. Meteorites are composed of volcanic materials and show no traces of any animal or vegetable life. They have been found only in the most recent geological beds. Their chief constituents are unoxidized compounds. They are low in silica and alumina, and rich in free iron, ferrous oxide, and magnesium oxide. They have no exact counterpart in the terrestrial rocks.

J. S. H.

Royal Photographic Society of Great Britian. The seventy-fifth annual exibition will be held September 13 to October 11, inclusive. The entire field of photography will be covered and will be arranged as follows: Section I, pictorial photography; Section II, colour photography; Section III, natural history and scientific and technical photography, useful photographic devices, and Section IV, kinematography.

American scientists are invited to submit prints showing the use of photography for scientific purposes and its application to spectroscopy, astronomy, radiography, biology, etc.

Prints for the exhibition should be mounted and may be sent to Mr. A. J. Newton, Eastman Kodak Company, Rochester, N. Y., who will again take charge of American material for the scientific section.

THE MEANING OF THE CRYSTAL.*

BY

SIR WILLIAM HENRY BRAGG, K.B.E., C.B.E., F.R.S., D.C.L., LL.D., D.Sc.

In the time which is allotted to me I should like to explain, if my audience will allow, the scope of the work in which, with my son and others, I have been recently engaged. I must first beg to remind you of certain facts. The elements of construction of the universe are the atoms, of ninety-two different kinds. The first constructive step is the assembling of the atoms into molecules. A molecule is a company of atoms in an association, which has some permanence great or small. The number of kinds of molecules is enormous. The water molecules consist of two atoms of hydrogen and one of oxygen; the molecule of ordinary salt contains one atom of chlorine and one of sodium; the molecule of an organic substance is generally more complicated, as for example that of naphthalene which contains ten atoms of carbon and eight of hydrogen. If the atoms are likened to the letters of the alphabet, the molecules must be compared to words.

The next step in nature's architecture is the linking of molecules to form solid substances, such as the subjects which we see around us and ourselves. The properties of all substances depend upon the way the molecules are put together, just as a house, or its interior, has a character and a usefulness, which depend upon its design, or just as the meaning of a sentence depends on the words it contains and on the way they are arranged.

This second step is not always made: The hindrance to its accomplishment is heat. Heat is a mode of motion, when for example the molecules of water are set in very rapid motion by imparting sufficient heat to them. The forces that would make them combine are overcome; the molecules exist as independent individuals and we have water vapor or steam. With less heat and less motion the molecules are always in

* Presented at the Medal Meeting held Wednesday, May 21, 1930.

partnership, but always changing partners, and we have water. Still less heat, and the molecules become permanently attached to each other in unchanging positions and thus ice is formed. Some molecules feel heat more than others, so that at ordinary temperatures some substances are solid, some liquid and some are gases.

It is the great aim of scientific research to connect the properties of a substance with the design of its construction. Gases have the simplest design, and the laws of gases are fairly well understood. Liquids come next, and we know something of their law also. In particular we have learned much of what happens when liquids of different kinds are mixed together; we have watched when molecules pull each other to pieces and make molecules of new patterns out of the old. This is the province of science which we call chemistry. The enormous advances in pure and applied science, for which chemistry is responsible, show how great are the results of research even in this limited field.

But when we come to solids we have to admit that we know very little indeed of the way in which their properties depend on their composition. The fact is that their properties depend on the arrangement of the molecules; these now have definite positions, and the pattern of the arrangement is all important. There was very little of this in liquids and none at all in gases. To make headway we must therefore learn the laws of arrangement. Until recently this has not been possible and we have been unable to enter a field of research which may well turn out to be the richest of all fields. But the x-rays have now opened the door for us; let me briefly explain how.

I must first say a few words about the capacities of our eyes. It is a strange fact that the eyes of men can see only a minute fraction of the things and the happenings that surround them. The light which brings us our knowledge, daylight, artificial light or lamplight, is narrowly limited to quality, and on that account, tells us only a small part of the whole tale. We are accustomed to recognize differences in quality. We speak of red, green, blue and indeed of an infinite variety of shades. The student of physics estimates their differences by reference to the standard of wave-lengths, the

waves referred to having their being in a hypothetical medium called the ether. He is not quite sure, in these days, of the amount of reality which should be assigned to these waves, but that is of far less importance than it sounds. The ether and its wave-length furnish for us a most useful language in which to express our thought and measurement. It then appears that the length of the ether waves may lie anywhere between very wide limits. In vision we use a minute section of that range. If we had never found any other means of detecting ether waves except our eyes, we might never have known the limits to our knowledge. But now, as I may remind you, we use very long invisible waves for transmission by radio, and, quite frequently, short invisible rays for the purposes of photography.

Now the quality or wave-length of the light determines that we can see by its means. Small details can be made out by short waves, and become less distinct if the light is of longer wave-length. Even within the narrow range of vision this difference can be observed. In certain microscopes used by biologists only light of extremely small wave-length is employed, the smallest that can be brought to bear upon the photographic plate, or the human retina, and in this way the power of the microscope is extended. On the other hand, it is curious to observe what a difficulty there is in picking up details in a red light, although the wave-length is only twice that of the shortest visible blue.

This strange limitation surely prompts our inquiry as to the reason, if one can be given. It is a fact that waves shorter than the visible cannot penetrate the miles of the atmosphere; so that even if our eyes could see them they would have no use for their powers. If our eyes responded to waves much longer than the normal we should certainly miss much detail that we value. Again it is a fact, of an entirely different bearing, that the perception of light depends on a curious process in which electrons are shifted out of their usual positions in the atoms of the retina: now, the shifting cannot be accomplished if the wave-length of the light is more than about a thousand times longer than the diameter of the atom. As atoms of all sorts have sizes which do not differ widely among themselves, a certain limit is set to the light which the

eye, as constituted, can detect. The waves must not exceed a certain length. Since the eyes of all creatures are made and act in much the same way, that which is light to one is light to all. Sir John Lubbock thought that ants could see blue light better than red, and I have seen it stated that certain insects do not appreciate light that has come through yellow glass. Whether these are actual facts or not, it is certain that the range of vision is very small. I do not know that any of these considerations answer the question, why? Mathematicians tell us that a ray of light, the emblem of directness, in continuing its way through space will in time return to where it began, and if we seek to distinguish between cause and effect, we are apt, proceeding step by step, to be in much the same case and to find that the last effect is also the first cause.

The consequence of the limitation is a corresponding restriction of the visible world. We are normally unconscious of all but a fraction of our surrounding. We have tried to extend our powers. We have first made use of the simple lens, then of the microscope, trying by these means to give to our eyes the more extended use of the light waves that can be seen. But to this effort there is a limit. When the optician has done his wonderful best, and when the shortest light waves are used, there is necessarily a halt; and at one time it seemed that the halt must be a permanent stop. But what new worlds, or rather new comprehensions of the old world have been opened up by these means alone! We are so accustomed now to the new vision that we have forgotten how strange it must have been to the early users of its powers. When Hooke wrote his Micrographia in the middle of the seventeenth century, he was in a mood of amazement at what the newly invented microscope told him. Section after section of this fascinating book describes the wonderful and hitherto invisible details of common objects, a hair, a piece of silk, a needle point and so forth. No doubt there were those who thought that these incursions into a new world of knowledge were unjustifiable, and what the eye could not see naturally was not worth seeing, and was not intended to be seen. We have learned that these minute things and happenings affect deeply and immediately our health and happiness

and our ability to use the resources of nature. And every improvement in the use of ordinary light by the microscope has added to our realization of the infinite and the unity of nature.

But, as I have said, where we have made the use of ordinary light, we come to a dead stop in this direction. It is here that x-rays, being what they are, furnish us unexpectedly and magnificently with a new range of vision. Consisting of ether waves, in the same sense that light so consists, but being some ten thousand times shorter, they can take note of details which are far finer than light can show us. It is very important to realize that minuteness does not mean insignificance nor want of relation to ourselves. The world which they can portray is as full of richness and variety, movement and interest as that which we see normally. It is true that our eyes see none of it, and so it is not associated with the ideas of beauty in form and colors. We cannot thoughtlessly take pleasure in it, as we may in the other. We must grasp what the x-ray tells us by means of delicate and complicated scientific methods, and our admiration and interest are of the mind only.

What sort of things do we now perceive? We see, if I may use the word in a broad sense, that arrangement of atoms and molecules in the solid body, of which we have been so eager to obtain knowledge. We stand in front of nature's architecture and examine her use of the elements in her construction. And here I must speak of a very important matter. We should still be unsuccessful did we not avail ourselves of one of nature's most remarkable characteristics, one which we have not indeed fully appreciated until now. It is her extraordinary tendency to regularity and order. If it were not for this uniformity, even the new rays could not help us. The effect of a single atom upon x-rays is far too small to detect. The effect is there, as it would not be with visible light, but it is insufficient in quality. But nature arranges her atoms in regular order in millions of millions: and the combined effect is big enough to affect our instruments. It is just as when the wind turns over all the leaves of the poplar tree at the same moment and the whole tree appears silvery grey, and so we learn what we could not have observed from

the behavior of a single leaf. A more exact analogy is found in certain colorations of nature, in the hues of butterflies for example, where a regular assemblage of fine scales makes for color, though each scale is too minute to be visible.

We see for example the atoms of carbon in the diamond and their perfect alignment according to a simple plan which gives every atom four other atoms as neighbors equally and regularly spaced about the first. We begin to understand how the design gives the diamond its unique hardness. We see the carbon atoms rearranging themselves according to a new plan to make the soft and slippery graphite. We see the atoms of oxygen, which far exceed all others in number, drawn up in regular order like a pile of shot to form the structure of most of the earth, and held together by atoms of silicon, magnesium, aluminium and so forth. The beautiful forms of the crystals of snow and ice are observed to be derived from the underlying and particular arrangement of the oxygen and hydrogen atoms. We begin to understand the details of construction of those long chains of certain atoms which are of such tremendous importance in the construction of living organisms. It is not to be forgotten that chemical investigation has long made us aware of their existence; but now we see, I think it is fair to say, what hitherto we have only inferred. We get a first rough idea of the actual forms of those curious hexagonal rings of carbon (the benzene ring) which are also of first importance to living things, and in other structures are the basis of dyes and many other great classes of compounds. It is indeed the whole range of nature's first compiling of atoms and molecules to form ourselves and the things about us that now opens to our view. Our untrained eyes do not yet interpret all, even a small fraction, of what they see. But as results accumulate and workers grow in number and power, so at the same time our interpretation becomes more accurate and effective. There is infinite opportunity for research, first of all in description of what the x-ray reveals, just as Hooke disclosed what the microscope told him, and then the greater and even wider enterprise of connecting the structure of bodies with the properties which they possess. You will understand the fascination of this new field of research.

THE PROBLEM OF THE MECHANISM OF SPARK DISCHARGE.

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INTRODUCTION.

For many years the theory of the mechanism of spark discharge as derived by Townsend [1] has been more or less widely accepted as essentially describing the phenomenon. This theory in essence ascribes the spark as being due to conditions set up in the gas between the electrodes such that there is a continuous supply of electrons from the neighborhood of the cathode produced by the interactions of the rapidly moving positive ions with other gas molecules or with the electrodes.

In the mechanism of the spark at atmospheric pressure between plane parallel electrodes however a serious discrepancy arose in past years which has caused some workers to abandon this elegant theory.[2,3] The difficulty lay in the fact that with the fields of the order of 30,000 volts/cm. usually causing spark discharge at this pressure the positive ions could not possibly in sufficiently large numbers get the energy to produce the phenomena required. It was particularly emphasized by the writer [4,5] in recent years that the theory could still be applied if a gratuitous assumption as to the fields at breakdown, acting on positive ions near the cathode, be abandoned. This gratuitous assumption was that the fields at the instant of breakdown were uniform. If actually as a result of the dark current preceding breakdown there are space charges formed which produce fields near the cathode

[1] Townsend, J. S., Electricity in Gases, Oxford, 1915, 322, 330 and 429.
[2] Holst and Oosterhuis, *Phil. Mag.*, **46**, 1117, 1923.
[3] Taylor, J., *Phil. Mag.*, **3**, 753, 1927, Proc. Roy. Soc. **114***A*, 73, 1927.
[4] Loeb, L. B., JOUR. FRANK. INST., **205**, 305, 1928.
[5] Loeb, L. B., *Science*, **69**, 509, 1929.

high enough to cause positive ions to generate the necessary ionization the Townsend theory may be retained. This suggestion seems now to be more or less recognized.

In 1928 the writer [4] showed that positive ion currents at 30,000 volts/cm. could easily produce the fields required. This led to the prediction that the positive ion mechanism for the production of such fields must cause a *true minimum* "spark lag" of 10^{-5} seconds. A similar conclusion is due independently to Rogowski.[6] Now the minimum spark lag had been measured in 1917 by Pedersen [7] using a somewhat uncertain method and had been found to be some 10^{-7} seconds (5×10^{-8} to 5×10^{-7}). Recent more direct measurements of Rogowski,[6] Tamm,[8] Burroway,[9] Torock [10] and Beams [11] published simultaneously with and after the writer's paper have shown that this time lies around 10^{-8} seconds.* Hence one must look elsewhere for the mechanism for production of the space charges than the motion of the slow positive ions.

It apparently independently and nearly simultaneously occurred to the writer and to A. von Hippel and J. Franck [12] that a mechanism might be invoked for this process through the use of the rapidly moving electrons in the gas. The mechanism assumed in the two papers differed somewhat and furnishes the basis of this article.

The writer calculated the velocity of the electrons at the sparking fields 30,000 volts/cm., which are initially uniform,

[6] Rogowski, W., *Archiv. f. Elektrotechnik*, **20**, 99, 1928.

[7] Pedersen, P. O., *Ann. der Phys.*, **71**, 317, 1923.

[8] Tamm, R., *Archiv. f. Elektrotechnik*, **20**, 1928.

[9] Burroway, *Archiv. f. Elektrotechnik*, **16**, 14, 1926.

[10] Torock, J. J., *Trans. A.I.E.E.*, **47**, 177, 1928, *ibid.*, **48**, 46, 1930.

[11] Beams, J. W., JOUR. FRANK. INST. **206**, 809, 1928; also *Bulletin Amer. Phys. Soc.*, **5**, 6, 1930.

* The difficulty in setting an exact value for the minimum spark lag lies in the inaccurate use of the word by different workers. Actually this time extends over the period when a potential producing ionization by collision, or even nearly the sparking potential is applied until the sharp drop in potential indicates that the gap has broken down. The minimum value is the one in which the statistical element of Laue and Zuber [13] is eliminated. The present estimates range from 10^{-9} sec. to 10^{-7} sec. and the most reliable data come from Rogowski [6] giving 10^{-8} sec. with small over voltages.

[12] von Hippel and Franck, *Zeits. f. Phys.*, **57**, 696, 1929.

[13] von Laue, M., *Ann. der Phys.*, **76**, 261, 1925. Zuber, K., *Ann. der Phys.*, **76**, 231, 1925.

using electron mobility data in air taken for low fields. He estimated a velocity of 10^7 cm./second. In 10^{-8} second therefore the electrons can only travel 10^{-1} cm., so that a mechanism for breakdown has to be devised which gives adequate space charges near the cathode in which electron clouds move only 10^{-1} cm. By some inexplicable numerical blunder in deducing α the number of pairs of ions formed by an electron per cm. path at atmospheric pressure from Townsend's experimental data for high field strength and low pressures the writer [5] set the number as 400 instead of 40, as it should have been. (Obviously an error in the decimal point.) This assumption led to such a value for the ionizing efficiency (theoretically not unlikely, but practically so far not observed) that it was possible to generate entirely adequate local potential gradients in the field by means of electrons moving but 1 mm. as computed above. To realize a sparking mechanism on the basis of such conditions a *"chain" mechanism* was devised which readily both explained the form and nature of the usual spark discharge as well as the *statistically* [13] observed time lags in sparking. If now the data for the ionizing efficiency in a gas at atmospheric pressure is tenfold lower, as indicated by the correct extrapolation of Townsend's data, the chain theory cannot be applied in spite of its palatable form.

Von Hippel and Franck on the other hand assumed electron velocities of 10^8 cm. per second for their electrons at 30,000 volts per cm. This permitted the whole distance (1 cm.) between the plates to be traversed by the electrons and so built up space charges of a more uniform nature between the plates. They used for the ionizing efficiency of electrons (α) some extrapolated values also taken from Townsend's data as deduced by Schumann. Their values were somewhat lower than the corrected ones estimated by the writer (e.g. about 18.5 instead of 40). With this data they found that one set of electrons crossing the 1 cm. between the plates would not suffice to give the gradients required. With increasing field distortions due to successive sets of electrons which each time increased the value of α these authors found that in several sets (from 4 to 10) of electrons the adequate fields could be built up. This mechanism

increases the assumed time for breakdown (true minimum spark lag) to 10^{-7} seconds. If, as is most probable, these writers *over-estimated* the electron velocities by at least four-fold then their theory requires a real time lag of 10^{-6} seconds which is not in accord with the experimental observations.

It follows from the discussion given that the experimental data at hand enable one to draw two fundamental conclusions concerning the mechanism of spark discharge at atmospheric pressure. These conclusions are (1) that if we assume non-uniform potential gradients of high value between the electrodes the theory of Townsend suffices in general to describe the mechanism of spark discharge, and (2) that such fields can be built up in the short time intervals observed by a mechanism dependent on the high velocity of the electrons relative to the positive ions existing during the *initially* uniform potential gradients at sparkover.

The two detailed mechanisms proposed for the generation of high fields by mobile electrons however differ in certain essential points. It appears therefore worthwhile to review briefly the fundamental quantitative data concerning the phenomenon of spark-over between the parallel electrodes at atmospheric pressure in general, as well as with regard to these two mechanisms, in order to gain a proper understanding of the problem. This will be accomplished under the following five headings, (1) Ionization by positive ions; (2) Values of α required by the values of β to permit the Townsend mechanism; (3) Electron velocities at high fields; (4) Calculation of the values of α to give high gradients in 10^{-8} seconds; (5) Theoretical evaluation of α.

1. THE IONIZATION BY POSITIVE IONS.

On this question there are relatively few reliable data, except those of Townsend [1] from his measurements of β/P as a function of X/P at low pressure and the recent work of Sutton [14] which must be extrapolated for our purposes and which seems to be questioned by some. At fields of 1.33×10^5 and 3.0×10^5 volts per cm., gradients five and ten times the normal sparking gradients in air, Townsend at low pressures observed values of β about 1.3 and 18.0 ions per cm. path per positive ion extrapolated to atmospheric pressure. These values are

determined indirectly from a possibly complicated phenomenon and are unquestionably too high, as will be seen. Sutton[14] obtains values for Na^+ ions in N_2 and air at 100 volts of the same order as those for neon. The results give the number of ions formed per 100 volt positive ion at 1 mm. pressure per cm. In the absence of exact figures for air the value for neon at 100 volts can be used which is 0.1. The kinetic theory mean free path under these conditions is of the order of 1×10^{-5} cm. at N.T.P. Thus we can estimate that these ions make on the order of $1/7.6 \times 10^{-3} = 132$ impacts in this distance, unless the mean free paths are abnormally great at these velocities as indicated by Kennard.[15] In that case there will be about half as many impacts. Hence Sutton's work would indicate that positive ions of 100 volts energy might on the average ionize by impact once in 132/.0.1, or about once in 10^3 impacts. For slower ions, those having just the ionizing energy of $1\frac{1}{2}$ times the ionizing potential estimated as essential for ionization by Franck,[16] say 25 volts, the value will be at least 10 times as great. Hence these results, if correct, might lead one to expect that only once in 10^4 impacts with molecules can a positive ion having 25 volts energy ionize in air. This means that the probability of ionization of positive ions having the ionizing energy of about 25 volts in air is less than 10^{-4} and even perhaps 10^{-5}. It is now essential to calculate how readily a positive ion can acquire the energy of 25 volts essential for ionization, and what fields are required at atmospheric pressure to give a value of β which might reasonably lead to a spark on the basis of the Townsend mechanism.

We may assume that the ion gains the ionizing energy on a single free path. On the average it can probably gain energy over several free paths. For the sake of simplicity however the assumption that all energy gained from the field is lost at the end of each free path may be used. It then follows from Townsend's theory of ionization by collision by ions that the chance of an ion gaining v_0 volts when its mean

[14] Sutton, R. M., *Phys. Rev.*, **34**, 547, 1929; **33**, 364, 1929; **35**, 694, 1930.

[15] Kennard, *Phys. Rev.*, **31**, 423, 1928.

[16] Franck and Jordan, Anregung von Quantensprungen, Springer, Berlin, 1926, p. 188.

free path is $\lambda_0 760/P$ (P = pressure in mm. of mercury) in a field of X volts per cm. is

$$b = \frac{1}{\lambda_0 \frac{760}{P}} e^{-\left(\frac{\epsilon_0}{\lambda_0 \frac{760}{P} X}\right)}.$$

Now for a positive ion of average velocity between 0 and 25 volts the mean free path is not known but probably lies between a little less than the kinetic theory value to about twice that value as shown by the work of Ramsauer and Beeck [17] and of Kennard.[15] The value of λ_0 is extremely important in this connection as it goes into the exponential term. A little calculation will show that if the product of b and the probability of ionization are to give a value of β for positive ions of a rational magnitude then we must choose X as 3×10^5 volts per cm. if λ_0 has the kinetic theory value of about 1×10^{-5} for air, or 1.5×10^5 volts per cm. if λ_0 is twice as great. Under these assumptions, we find $b = 25$ while if we make $X = 1.5 \times 10^5$ and have $\lambda_0 = 1 \times 10^{-5}$ we find a value for $b = 6.1 \times 10^{-3}$. The values for β which will occur, assuming the chance of ionization to be of the order of 10^{-4}, or 10^{-5}, will lie between the extremes of 2.5×10^{-3} and 6.1×10^{-8}, at these fields of 3×10^5 and 1.5×10^3 volts per cm.

It is therefore clear that unless the *non-uniform* potential gradients occurring *before* sparkover exceed 1.5×10^5 volts per cm., even with the most optimistic assumptions as to the ionic mean free path and ionizing efficiency of positive ions of 25 volts energy in air, the values of β, the essential constant, become entirely too small to give a reasonable value. The calculations also show that Townsend's original data on β must be seriously in error when extrapolated to atmospheric pressure. This may be due to the fact that in measuring β Townsend had space charges present which increased α near the cathode and gave him abnormal results.

2. VALUES OF α REQUIRED FOR THE VALUES OF X AND β ASSUMED ABOVE TO INITIATE SPARKING ON THE TOWNSEND MECHANISM.

On the Townsend theory a spark passes when β, the number of ions per cm. path produced by positive ions, is related

[17] Ransauer and Beeck, *Ann. der Phys.*, 87, 1, 1928.

to α, the number of ions produced per cm. path by electrons, by the equation

$$\alpha = \beta e^{(\alpha-\beta)d}$$

The calculations for α may be made by assuming a value of β of 6×10^{-9}, with a distance d over which the spark must pass, of 0.1 cm. for the case where this spark begins over one of the writer's assumed short elements in the "spark chain" mechanism. Longer values of d require a much smaller α so that the assumed value gives an extreme case.

This equation at once gives a value of α of about 250, which is well below even the very low value of 1,980 given by Townsend's extrapolated results in air for the field of 1.5×10^5 volts per cm. assumed to exist in the abnormal gradient just before breakdown. Had an abnormal gradient of 7.5×10^4 volts per cm. been assumed, the value of β would have been 1.5×10^{-13} giving an α of about 400. Under these circumstances we would be very close to the value of 500 observed by Townsend at lower pressures for X/P of the value 100 corresponding to $X = 7.5 \times 10^4$ volts at 760 mm. With values of β as small as the latter value however there are probabilities that other processes occuring at the electrodes could cause the spark, a conclusion which seems at variance with experimental evidence on the independence of sparking potential and electrode material at higher pressures. It is thus probable that the abnormal fields required to cause a spark breakdown must be of the order of at least 1.5×10^5 volts per cm. and it becomes a problem to study the conditions which could cause such fields by electron ionization alone in 10^{-8} seconds.

3. THE ELECTRON VELOCITIES AT HIGH FIELDS.

The velocities of electrons at high fields such as those cited above cannot well be estimated from the values of electron velocity measurements at low fields at atmospheric pressure. K. T. Compton [18] has however developed a theory of electron velocities which holds fairly well for low fields and which he has also adapted to very high fields where the molecular velocities of thermal agitation may be neglected. There are

[18] Compton, K. T., *Phys. Rev.*, **22**, 333, 1923.

two equations, (*a*), assuming elastic impacts between electrons and gas molecules, and (*b*), assuming inelastic impacts. A third estimate may be made from (*c*), the Langevin [19] equation for electron mobility assuming an *average electron energy*. These relations are

(*a*) Elastic impacts between electrons and molecules,

$$K_e = .707\sqrt{\frac{e}{m}\frac{\lambda}{X}\sqrt{f}}, \text{ where } f = \frac{2m}{M}.$$

(*b*) Completely inelastic electron impacts with molecules,

$$K_i = \sqrt{\frac{\pi}{2}\frac{\lambda e}{mX}}.$$

(*c*) $K_L = .815\frac{e}{m}\frac{\lambda}{c}$; and $c = \sqrt{\frac{2Ve}{m}}$.

Here λ = electron free path, assumed at these speeds as about 10^{-4} cm.

e = electron,
m = mass of electron,
X = electric field strength, *initiating* sparkover, 3×10^4 volts/cm.,
M = mass of air molecules,
V = average energy of electrons at 30,000 volts/cm. assumed to lie between 1 and 15 volts and taken on the average as 9 electron volts for this problem.

Calculation yields for the velocity at 30,000 volts/cm., i.e. 30,000 (K per volt/cm.):

(*a*) $K_e = 4 \times 10^6$ cm./sec.,
(*b*) $K_i = 9 \times 10^7$ cm./sec.,
(*c*) $K_L = 2.5 \times 10^7$ cm./sec.,

The value of K_e is doubtless too low as it assumes *no* inelastic impacts between electrons and molecules at all and that the electrons acquire their terminal velocities of the order of 325

[19] Langevin, P., *Ann. Chim. Phys.*, **5**, 245, 1905; **28**, 317, 495, 1930. See also Loeb, L. B., Kinetic Theory of Gases, McGraw-Hill, N. Y., 1927; pp. 443 ff and 496 ff.

volts. The impacts are *quite elastic* up to energies of some 5 to 10 volts; above this value they are not so elastic. Hence the K_i is far too high. The value of K_L gives probably a fairly close estimate to the true electron velocities as it is theoretically based on the same assumptions as (*a*) and (*b*) but arbitrarily assumes a *likely* average electron energy and hence estimates elasticity more correctly.

This velocity of 2.5×10^7 cm./sec. however makes the theory of von Hippel and Franck untenable when pressed to an extreme interpretation. The reason for this lies in the fact that breakdown occurs in times of the order of 10^{-8} seconds so that the mechanism for obtaining the high fields which they postulate can hardly be set up in such short periods with electrons of 2.5×10^7 cm./sec. velocity.

Since they postulate such a mechanism largely due to the fact that α as taken from Townsend's low pressure data is too low it remains to be seen whether there is a theoretical basis for accepting such a low value for α. If higher values for α are likely, then the von Hippel-Franck mechanism is not needed since the mechanism set up by the writer can be used. It is therefore next essential to calculate the value of α required on the writer's "chain" mechanism and to regard the theory of the nature of α.

4. CALCULATIONS OF THE VALUE OF α REQUIRED TO GIVE GRADIENTS OF 1.5×10 VOLTS/CM., AT A UNIFORM GRADIENT OF 3×10^4 VOLTS/CM.

If the electron velocity is of the order of 2.5×10^7 cm. per second at fields of 3×10^4 volts per cm,. a discharge can only occur at these fields in 10^{-8} seconds if the electrons can create adequate space charges in this time interval. Since in 10^{-8} seconds an electron can only travel 0.25 cm. in fields of 3×10^4 volts/cm. this distance must be of the order of the length of the link in the writer's chain mechanism. It is furthermore clear that it is only by such assumed short distances of travel of electrons in the field that one can have sparks produced within actually observed time intervals. Now such an electron creates in its 2.5 mm. of path n new electrons and positive ions according to the well known Townsend equation which says $n = n_0 e^{\alpha d}$. Here $d = 2.5 \times 10^{-1}$, $n_0 = 1$ and α is to be found so as to give enough positive ions to build up a field of 1.5×10^5 volts per cm. If one assume that the dis-

tance of the cloud of *positive* ions left by the initial ionizing electrons is on the average 2.5×10^{-1} cm. from the cathode (an overestimate) it is at once possible to compute n the number of positive ions required to give a field of 1.5×10^5 volts/cm. Consider the field due to a charge $+q$ placed r cm. from a conducting surface. From the theory of electrical images, the density of charge σ at r cm. directly opposite the charge q on the conducting surface is

$$\sigma = \frac{-q}{2\pi r^2}.$$

Near such a surface density of charge σ the field is $4\pi\sigma$ and this must equal the field X, or 1.5×10^5 volts/cm. Hence $X = 4\pi\sigma$, or $\sigma = X/4\pi$, whence $X = -2q/r^2$. Now $X = 1.5 \times 10^5$ volts/cm. $= 5 \times 10^2$ E.S.U./cm., $r = 2.5 \times 10^{-1}$ cm., whence $q = 15.6$ E.S.U. Since $ne = q$, one has $n = 15.6/4.77 \times 10^{-10} = 3.3 \times 10^{10}$ positive ions. Hence α is at once determined by $3.3 \times 10^{10} = e^{.25\alpha}$, which gives α close to 100.

Thus for an electron moving with what is probably its true speed in a field of 3×10^4 volts/cm. abnormal fields near the cathode of the proper order of magnitude can be built up by ionization in 10^{-8} seconds if α is of the order of 100 instead of 40. If a second electron is liberated within the region near the cathode shortly after the first electron has built up a field of perhaps 8×10^4 volts/cm. in its first 2 mm. the second electron in the higher field can surely build up a space charge sufficient to start the disruptive mechanism.

As seen from the foregoing the value of α is the critical point in the mechanism and its seems worthwhile to glance at the theoretical value of α at fields of 3×10^4 volts/cm. to see whether there is a possibility of Townsend's value being low.

5. THE THEORETICAL CALCULATION OF α.

Compton [18] has shown that the differential equation of loss and gain of energy U by an electron in an electrical field X in a gas is given by

$$dU = \left(X - \frac{fU^2}{.441\lambda^2 X}\right) dx,$$

where dx is the distance moved over by the electron. This may be integrated to give

$$x = \frac{0.33\lambda}{\sqrt{f}} \log \frac{\sqrt{\frac{.441}{f}\lambda X} + U}{\sqrt{\frac{.441}{f}\lambda X} - U},$$

in which the symbols have already been defined elsewhere. f represents the fraction of electron energy lost at an impact, which for elastic impacts is $f = 2m/M$ approximately, or 3.74×10^{-5} for an electron in air. If U be set as an ionizing energy of 15 volts and λ as 10^{-4} cm., the value of the distance which an electron must cover in the field X to gain this energy may be calculated as 4.8×10^{-4} cm. Thus an electron can gain the ionizing energy under the above conditions 2.08×10^{3} times in 1 cm.

Now it may be urged that the energy loss of electrons in air is not given by the fraction f per electron impact with a molecule cited above for the early work of Franck and Hertz [20] and later of Baerwald [21] showed that f appeared higher in N_2 or H_2 gas than it is in the inert gases.

As Harries [22] clearly showed those early results of Franck and Hertz and Baerwald were statistical and caused by too great a dispersion of initial electron velocities. What really happens in these gases is that electrons gradually get energy up to a value at which they can transfer it either to (*a*) ionization, (*b*) electronic excitation leading to radiation, or to (*c*) a vibrational level in polyatomic molecules. Now the loss to *excitation* had long been recognized as a factor entering into the evaluation of α by the writer but never discussed in print. These exciting impacts however only serve to *reduce the number of electrons* such as calculated above which can get the ionizing energy in 1 cm., by removing a certain number due to exciting impacts. The same applies to the loss of energy to vibrational levels in which case Harries found that 5.2 volt electrons lose energy to such impacts at the rate of 1

[20] Franck and Hertz, *Verh. d. Deutschen Phys. Ges.*, **15**, 613, 1913.

[21] Baerwald, H., *Phys. Zeits.*, **26**, 868, 1925.

[22] Harries, W., *Zeits. f. Phys.*, **42**, 26, 1927.

in 110 impacts in N_2 and 1 in 31 impacts in CO. This merely means that while every one of the possible 2,080 times in which an electron gets the ionizing energy of 15 volts in air at $X = 3 \times 10^4$ volts/cm., it may potentially form a new pair of ions, the number of new pairs of ions formed is distinctly less owing to losses to vibrational or electronic excitation. It also means that if an electron with 15 volts energy does not ionize at once it may continue to add energy until it does ionize or cause resonance. Under these conditions again the total number of pairs of ions formed per cm. path will be less. The true value of α could be computed if ionization and excitation (electron and vibrational) probabilities at each energy of the electron were known. Since they are not known one may only conjecture. *Were excitation losses absent* while acquiring the ionizing energy one could quite safely put α as about 1/2 or 1/3 of the number 2,080, for from ionization produced by fast electrons it is well known that the average energy expenditure for fast electrons per pair of ions is about 30 volts and for slower ions it would not be much more than 45 volts. Now the probabilities of excitation for electrons between the excitation and ionizing energies is not very high, and above the ionization potential the ionization probabilities far outweigh the excitation probabilities. Hence it might be liberal to assume that due to excitation losses and inefficient ionization the number of potential ion pairs were reduced by a factor of 20. With this assumption the value of α computed would still be of the order of 100, a value quite sufficient for the purposes of the proposed theory. With a lack of accurate knowledge however it can only be said that α at atmospheric pressure and 30,000 volts/cm. might well be distinctly greater than the value of 20 to 40 assumed.

In any case one may conclude that the crucial point in getting a clear picture of the true mechanism of spark discharge in terms of Townsend's theory lies in clearing up the discrepancy between theoretical indications as to the value for α near sparking potentials, and the extrapolated experimental values.

6. DISCUSSION OF A RECENT THEORY OF SPARK DISCHARGE.

Another recent theory of the spark discharge *mechanism* has been proposed by Slepian [23] which is often quoted by

[23] Slepian, J., *Electrical World*, 91, 761, 1928.

engineers. In view of the fact that this theory appears to contain an erroneous impression concerning fundamental electronic mechanisms some of which are cogent to this paper a brief discussion may not be out of place. Virtually, Slepian has deduced from *assumptions* as to mechanism of the electron behavior in a gas in a high field and from the conditions existing *after* the spark gap has broken down that the *temperature* in the spark path is *exceedingly high*. The latter *fact* is borne out by recent work of Lawrence and Dunnington.[24] Slepian assumes that the ionization observed in the spark is a *temperature ionization* such as would be governed by the well known Saha [25] theory which, however, depends on temperature *equilibrium*. The fact is that once the spark is started and the enormous energies available are liberated, the spark filament has an ion density and a *temperature* which might be consistent with Saha's theory. These results however say nothing as to how this condition originated. Slepian *assumes* that in the *high fields electrons generate new ions and electrons by impact along filaments*, and that in these filaments the *electron currents directly give their energy to the gas* in very short time intervals so as to cause intense local heating by *electron currents*. This heating by *electron currents*, according to Slepian, leads to "temperature ionization" of the Saha type. The theory is plausible except for the fact that thermal equilibrium cannot exist in such short time intervals and that *electrons collide elastically with molecules and atoms*. Except when electrons excite or ionize molecules and atoms *they are practically incapable of directly transferring their energy to a kinetic heat agitation of the molecules* atoms and positive ions—i.e. to increase the temperature of the gas. (See section 5.) The electron energy goes almost selectively to *ionization and excitation* with very little transfer to energy of molecular agitation. It takes in fact *long periods* (10^4 impacts or more) in the life of an electron for it to impart its superfluous energy to *heat energy* of atoms and molecules directly by collision and still more so indirectly by radiation which also diffuses the energy. Hence the mechanism of heating of the gas and "temperature ionization" by electrons cannot play the

[24] Lawrence and Dunnington, *Phys. Rev.*, 35, 1930.
[25] Saha, *Phil. Mag.*, 40, 472, 1920.

essential role in the mechanism of breakdown of the gap. The initial ionization is an electron impact mechanism due to the field and far removed from the Saha conditions. As the potential gradients increase and the spark mechanism develops it may be expected that along the ionized path, the *positive ions* pick up energy in the field. This energy is quickly dissipated in impacts with molecules to energy of heat agitation (i.e. in each mean free path (10^{-9} seconds) the positive ion is losing a good fraction of its energy to neutral molecules). In this case the rate of energy transfer is high as shown by the discussion under (1), and by the time that the spark has passed, the electrical field by means of the positive ions has imparted the high temperature to the gas observed by Lawrence and Dunnington. At the same time *ionization by electrons and positive ions* has increased the ion concentrations to conditions approaching the Saha equilibrium at the temperatures of the gas inferred. It is only when the number of positive ions approaches the number of molecules in order of magnitude that such a condition as the above can arise in short time intervals, for the transfer of energy from the field to the gas is practically only by positive ions. The theory of Slepian is thus in error in that it is contrary to well established facts of interactions between electrons and molecules, while the conditions from which it might be inferred are actually produced at a later stage in spark formation by the interactions of *positive ions with the gas molecules in the field*, but *not* by electrons.

CONCLUSIONS.

With the quantitative survey given above one may draw the following conclusions.

1. If non-uniform local fields due to space charges of the order of magnitude of 1.5×10^5 volts/cm. can be built up by the ionization by electrons at uniform fields of 3×10^4 volts per cm. or more in air at atmospheric pressure the ultimate mechanism of spark discharge dependent on the ionization by positive ions postulated by Townsend suffices to explain the sparking condition.

2. These space charges must be built up at this field of 3×10^4 volts/cm. by electrons having a velocity not greater than 2.5×10^7 cm./second in periods of time which lie between 1×10^{-8} and 1×10^{-7} seconds.

3. Such fields might conceivably be built up by an electron in traversing distances of the order of magnitude of 1 cm. by the well known Townsend mechanism of ionization by collision for electrons. In general however the times involved in such processes would not be quite short enough, although nearly so. They would certainly not be short enough if the ionization by electrons were as inefficient as postulated by von Hippel and Franck, for these would require the passage of several electrons successively over this distance.

4. There is an essential difference evidenced in the computation of the fields built up by the motion of the electrons on the present analysis and in that of von Hippel and Franck. In the present analysis the local fields due to minute charge accumulations localized between the electrodes are calculated. In the paper quoted a study is made of the potential gradients in terms of the number of ions formed throughout the volume by an assumed initial current of photoelectrons from the cathode. The latter calculation therefore treats sparking as a uniform process which for the real time lag is very much dependent on the initial number of ions. From the writer's viewpoint only the statistical [13] spark lag is influenced by the number of initial ions present, while the minimum [6,7,10,11] value is uninfluenced by any such considerations, as experiment seems to show.

5. If the fields could be built up by the travel of electrons over distances of 2 mm. in these fields the spark being formed across the fortuitous paths so related as to form a continuous chain of ionization extending to the cathode, one could

(*a*) easily explain the shorter time intervals observed.
(*b*) the zigzag path of some spark discharges.
(*c*) the suppressed spark discharges of Torock.
(*d*) the statistical nature of the time lags near the sparking potential when few ions are present.
(*e*) the relatively small lowering of the sparking potential in the presence of intense photoionization at the cathode observed.
(*f*) the long time intervals observed recently at lower pressures by Steenbeck.[20]

[20] Steenbeck, M., *Naturwissenschaften*, 17, 981, 1929.

(g) independence of sparking potential of electrode material.

6. Calculations however show that in order that fields of 1.5×10^5 volts per cm. be built up by electrons moving only relatively small distances, e.g. 2.5 mm., the value of α must be materially higher than that computed from Townsend's low pressure values for air at $X/P = 39$ when extrapolated to atmospheric pressure at 3×10^4 volts per cm. initial gradient. The values of α of from 20 to 40 estimated must be increased by a factor of about 5–2.5 in order to make the mechanism suggested possible.

7. A theoretical study of the nature of α shows that it is possible that in fields where electrons gain about 2 volts per mean free path, values of α for $X/P = 39$ at 760 mm. exist which are distinctly greater than those assumed from Townsend's data. A definite decision cannot be made until actual quantitative data are at hand. This question is now actively being experimentally investigated in the writer's laboratory.*

* While this paper was in press a short note by W. Rogowski (*Naturwisschaften*, 18, 246, 1930) appeared giving recent measurements of Viehmann on minimum sparking time lags as a function of overvoltage and of Paavola on values of α as function of the field strength X at atmospheric pressure. In the work of Viehmann breakdown was found to occur in 10^{-8} seconds for overvoltages from 20–60% which corroborates the statement of the writer at the beginning of this article. Paavola's work about which no details are given reports values of α experimentally observed at $X/p = 41.7$ as 18, and at $X/p = 50.7$ as 50, taken at 760 mm. in air. This confirms the values of α assumed at $X/p = 40$ by Franck and von Hippel extrapolated from Townsend's data at low pressures, and is well below the writer's estimate. Values of β of a similar order of magnitude were obtained at X/p six times as great. This result requires verification in view of the high values of β found, and detailed publication must be omitted before the value of the results can be judged.

Recent work of Dunnington at California on visual observation of sparks within 5×10^{-8} seconds after breakdown are of considerable interest. With small overvoltages a considerable fraction of sparks observed with a Kerr cell shutter show the series of short path elements demanded by the writer's chain mechanism. Other sparks (the majority) show a straight path, with however three distinct elements. These are a very bright element emanating from the cathode, another shorter bright element emanating from the anode, and a fainter long bridge joining the two aforementioned elements. The form is never twice the same and depends on the relative sizes of the two electrodes (small sphere gap). These results which will be published, in part lend support to the writer's theory of spark mechanism under conditions of slight overvoltage.

POWER PARKING.[1]

BY

MILTON A. KENT,

President, Kent Garage Investing Corporation.

As civilization has advanced and the human race has expanded, transportation has ever been one of the most vital features of our culture. During the last twenty-five years, when the masses of population have centered in urban communities, the problem has not been solely how to care for the people in the matter of transportation, but rather how to care for the means of transportation used by them, namely: the vehicles which carry millions of people from one point to another.

The rapid expansion of the use of automobiles as a means of individual transportation has brought to all large cities a serious traffic problem. One of the real obstacles encountered in this traffic situation is not how to keep cars moving, but what to do with the cars that stand still! This problem did not exist twenty-five years ago, but today with the urban population ever greater, and human beings crowding into small areas, it is most serious and demands an immediate solution.

For many years traffic experts, city officials and zoning commissions have advocated the use of skyscraper buildings as automobile terminals for the myriads of vehicles that daily enter into the business sections of our cities; with the development of a mechanism known as the automatic electric parker these great skyscraper garages have become a reality.

This electric parker is simply a low, rubber tired towing unit, driven by a four horse power electric motor. It runs beneath the motor car and engages with the rear axle by means

[1] *Editors Note.*—This paper is a summary of a lecture delivered before The Institute, Thursday February 6, 1930, by Mr. M. A. Kent, the inventor of the systems described.

of an aluminum cleated coupler. It is operated from the platform of a high speed self-leveling elevator by the elevator attendant and eliminates all use of the automobile's own power after the driver has left it at the street level receiving floor of this new type garage (Fig. 1).

FIG. 1.

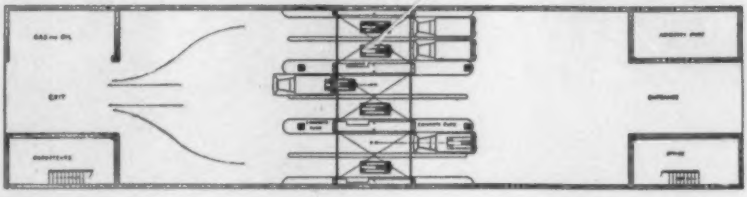
The electric parker is connected by a flexible conductor cable to the controls on the elevator. The cable is carried on an automatic reel mounted beneath the elevator platform. When the parker goes from the elevator, the cable is pulled off the reel; when the parker returns the cable is drawn back and rewound by the spring, or motor, operating the reel. By this device the slack is taken up and the cable is kept from coiling on the floor and protected from damage.

Two electric parkers are mounted on each elevator platform rendering service in this new type garage. Each parker is separately controlled by a fourway lever switch mounted, as shown in Fig. 1, beside the elevator control handle. A parker tows a car off and returns to the elevator, or goes out and tows

a car back to the elevator, in fifteen seconds, which is faster than a car can possibly be handled under its own power. This ability of the parker, in combination with the high speed self-leveling elevators, to bring a car to the ground floor without taking time to start the motor is naturally a great time saver.

In one skyscraper garage now in operation, there are three double width self-leveling elevators each carrying two motor cars side by side, as shown in Figs. 2 and 3. Double width

FIG. 2.



Ground floor sketch.

elevators have many advantages as they increase the storage capacity by the elimination of aisles and ramps, and cut labor costs. The elevators travel about one floor per second and stop automatically and accurately at the floor levels. They run at such speed as to give a rush hour capacity of about five cars per minute.

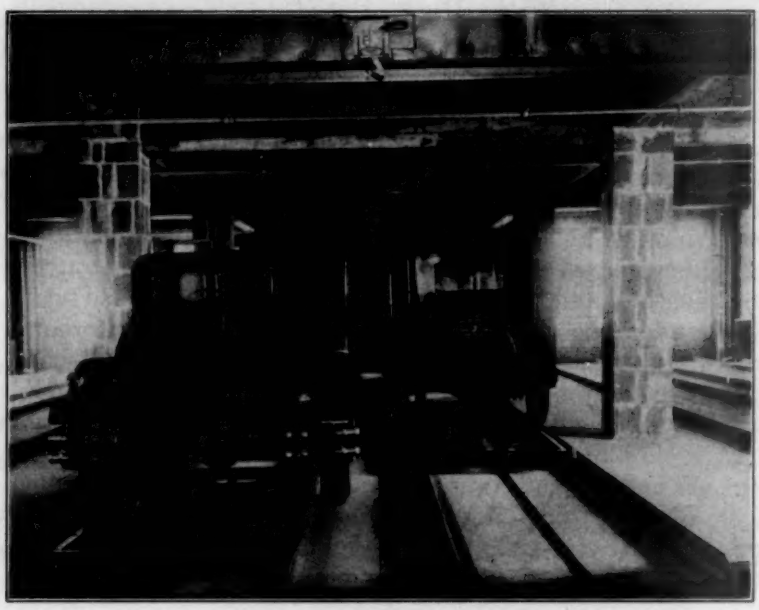
Architecturally, the skyscraper garage can be an asset to any district. So far as appearances are concerned, these buildings should take rank with the most advanced types of modern office buildings, meeting all zoning requirements.

This type of garage is of ordinary steel and concrete construction and usually has brick and hollow tile walls. Because of the purpose for which it is used, automobile parking, the space from floor to floor can be restricted to 9′ 8″. Of course greater ceiling height can be allowed if a convertible building is desired. With the structure being used only as a garage, no plastering, plumbing, employee stairs, washrooms, etc., are needed, and comparatively little heating, as a temperature of about forty degrees is always sufficient. As all cars are moved by the electric parker and never by their own

FIG. 3.

Entrance lobby, three double-width elevators.

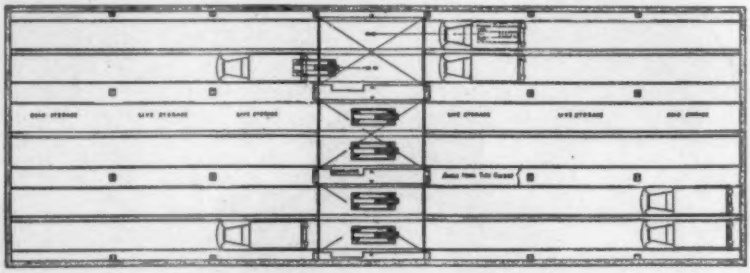
FIG. 4.



Floors, tireguards, interior finish of building.

power, there is no exhaust gas to be gotten rid of, and no need for any special ventilating equipment. The elevators carry flood lights, so that only a small amount of wiring is necessary on each floor. (See Figs. 4 and 5.)

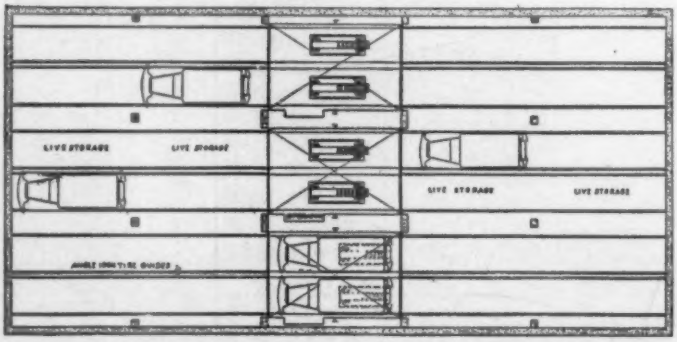
FIG. 5.



Typical floor plan, 2nd to 17th inclusive

The floors are of smooth concrete with four inch angle iron tire guides. Cars are readily removed, in the event of an elevator failure, simply by driving them on to the adjoining elevator (Fig. 6).

FIG. 6.



Typical floor plan, 18th to 24th inclusive.

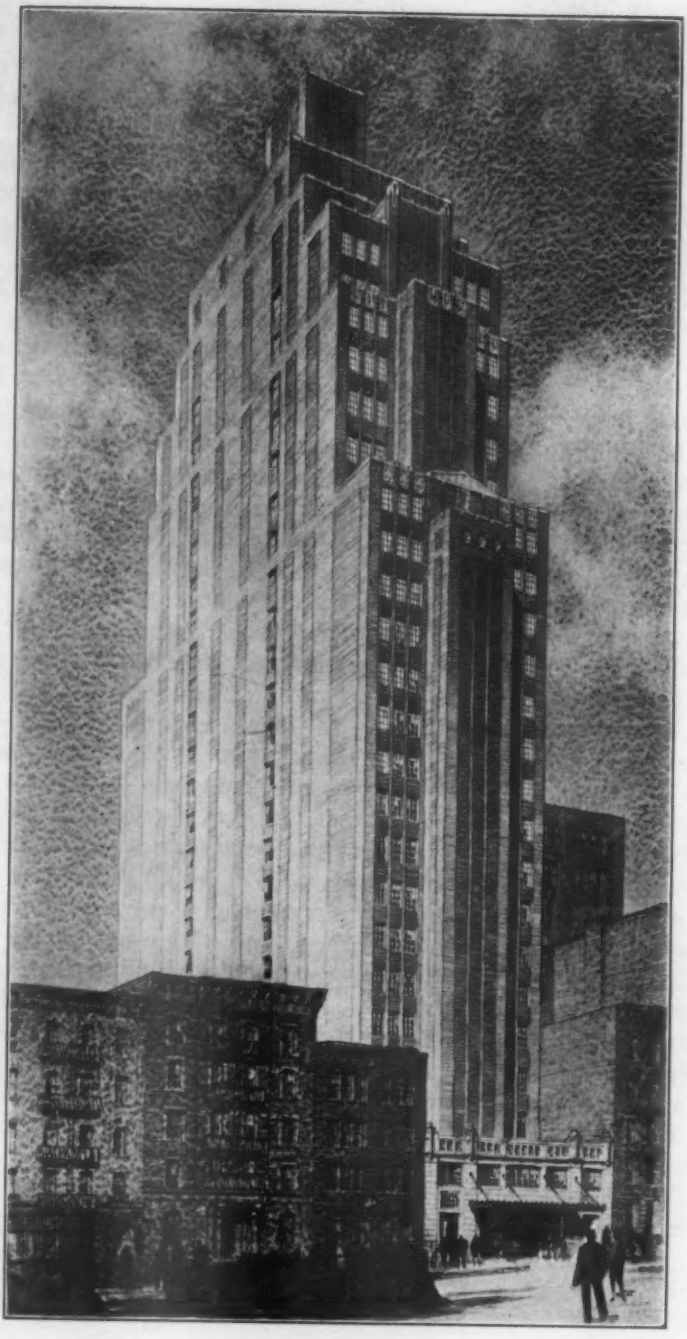
In order to facilitate the handling of cars, the front storage row to the right of the elevators, as shown in Fig. 7, is kept open for switching space most of the time: for example, if a second row car is called for, the car occupying a first row

space is simply towed onto the elevator by the electric parker and set across into one of the vacant spaces; the parker then

FIG. 7.

returns for the car called for. In this way, as the parker operation requires only about 15 seconds, extremely rapid delivery is obtained from all rear spaces.

FIG. 8.



The building is equipped with spacious rest rooms and has ample fire protection. The street level floor is used only for receiving and delivering. It extends the entire width of the building, has high ceilings, and no columns to interfere with easy entrance and exit.

Owing to the fact that every detail of the garage is operated by a series of controls in each elevator, a fewer number of more highly trained men are required than is ordinarily the case, and a higher standard of service can be expected.

No human hand touches a car after it is driven into the garage, and ignition, transmission, doors and windows may be locked if desired. The driver leaves his car, with brakes released, in front of the elevator door; it is then taken by the electric parker onto the elevator, thence to its assigned floor in the building. When the attendant stops the elevator, he manipulates the control of the electric parker and the car is towed forward or backward, as the case may be, to its storage space. When the car is required again, the number and location are signalled by telautograph to the elevator operator and the car is brought to the ground floor and set out for delivery in from one to three minutes. Without leaving his position on the elevator the operator receives, parks and delivers all cars.

An operating experience of some months shows the following salient facts about this system of electric parking: "A 'storage hotel' for one thousand cars was built on a lot fifty by a hundred and forty feet and was carried to a height of twenty-five stories. The capital investment per rentable storage space was approximately $1,600 which represents less than one-half the capital investment per car space which would be required for any other type of garage so far developed, and located on land costing the same per square foot. Any car stored in this 'hotel' can be delivered within three minutes after it is called for at the office, and in many cases delivery is made while storage charge is being collected. Car doors, ignition and transmission may be left locked, if desired, by the owner. 'No human hand touches the car after it enters the elevator' at the first floor."

These garages are already in operation in New York City. It is planned to build them throughout the country. Un-

doubtedly the combination of utility and beauty, as presented in these buildings of modern architecture made possible by the development of the electric parker, will add much to the comfort and convenience of modern civilization and to the solution of the imperative problem of the care of automobiles in cities.

The Radioactivity of Various Metals Taken from Old Roofs. A. BOUTARIC AND MADELEINE ROY. (*C. R., French Academy of Sciences*, Feb. 24, 1930.) In testing the ionization produced by the pieces of metal a Szilard electrometer of high sensitiveness was used. Normally the instrument was closed below by a plate of aluminum. In the tests this was replaced by one piece of metal after the other. When the face of the metal placed uppermost and consequently in a position to cause ionization in the electrometer chamber was that which had been exposed to the weather the speed of discharge of the instrument was much greater than with the aluminum in place. When, however, the upper surface of the metal was that which had been shielded from the elements the speed of discharge was about the same as with the aluminum bottom. In all instances there was a great difference in the discharge rate caused by reversing the roofing specimen. The largest ratio was found for zinc 20 years old taken from the roof of a chateau at an elevation of 1,050 meters. Lead was almost as effective while copper occupied an intermediate place. The results are interpreted as in opposition to explanations based upon possible disintegration of the metal by radiations from the sun or from space or upon the presence in the metal of radioactive impurities and in favor of adsorption by the metal of radioactive emanations from the atmosphere.

G. F. S.

THE MOLECULAR SCATTERING OF LIGHT FROM CERTAIN ORGANIC LIQUIDS.*

BY

NEIL B. REYNOLDS AND JOHN WARREN WILLIAMS.

The molecular scattering of light from solids, liquids, and gases has roused the interest of many investigators. Some have already shown its importance as a demonstration of the quantum laws, others have sought to use it as an analytical tool in probing the internal structure of chemical compounds. It is our purpose to attempt to discover in Raman lines a key to the linkages between atoms and to develop a tool for the investigation of the structure of more complicated molecules. We do not claim to have found a simple analytical tool, yet we feel that at least some progress in this direction has been made.

The more recent theory, involving intercombination of energy levels, has become complex. It will suffice for our purpose to state the original simpler explanation in brief. A beam of monochromatic light, passing into a polyatomic solid, liquid, or gas is scattered according to the classical theory. Observation at right angles to the direction of the incident light insures a minimum of the incident radiation entering the investigating instrument. Observation of the scattered light with a spectroscope shows that a portion of it has suffered not only an alteration in path, but also in frequency. Accompanying each of the strong original spectral lines are very much weaker satellites. According to the quantum theory, the energy associated with any light quantum is proportional to the frequency or the wave number of the light (wave number $= \nu = 1/\lambda$). Therefore, the difference in energy between altered and unaltered lines is measured by the differences of their wave numbers. The first notable characteristic of this new radiation is that these energy differences are perfectly constant quantities, independent of

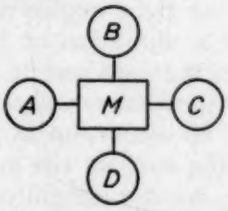
* Contribution from the Research Laboratory of the General Electric Company.

the wave-length of the exciting light and characteristic of the scattering medium.

The first observers of this phenomenon soon noticed that certain of the series of energy differences for any particular material corresponded passably well with the energy of the measured *near infra-red* absorption bands. This opened up an explanation. In all but a few cases the new lines were shifted toward the red, that is, had less energy than the exciting line as demanded by Stokes' law for fluorescence.

The work on band spectra has identified the near infra-red spectra of the diatomic gases as the typical rotation-vibration spectra, with the major portion of the energy due to the line connecting their centers. Semi-quantitative work on more complex molecules has verified this theory. Therefore we may safely attribute the near infra-red absorption bands to vibrations of the integral atoms within the molecule, and it is only a step to the assignment of different individual vibration energies to different individual interatomic linkages. Coblentz, in 1905, made a hasty survey of a large number of organic substances, and tried to connect absorption maxima and structural linkages, but with indifferent success.

Our simplest picture of the Raman effect is closely tied up with this. A quantum of energy, $h\nu_1$, in some way meets and interacts with a molecule:



For each of the linkages M–A, M–B, M–C, M–D there exist one or more characteristic vibration frequencies (ν_A, ν_B, ν_C, ν_D, ν_A', etc.) with energies corresponding to some infra-red wave-lengths between 1 μ and 100 μ. If this molecule is in a normal state (that is, is not excited), it can abstract from the quantum $h\nu_1$ sufficient energy to excite one of these characteristic vibrations. The remainder of the energy is reradiated as a new quantum according to the relation

$$h\nu_2 = h(\nu_1 - \nu_A).$$

The new quantum, $h\nu_2$, corresponds to a line shifted toward the red. If, however, the molecule under discussion is at the time of interaction with the radiation already in an excited state, it may do one of two things. The molecule may return to its normal state, delivering the energy released to the quantum and causing the reradiation of a quantum of wave number ν_2' given by

$$h\nu_2' = h(\nu_1 + \nu_A).$$

This is a line shifted toward the blue; an "Anti-Stokes Line" in the common terminology.

The other possibility is that the already excited molecule may absorb sufficient energy to raise it to a second excited level. The wave number difference for this resulting Raman line will not correspond to any observed infra-red absorption maximum, but rather to the difference between two such maxima. The rules governing these intercombination transitions are complex, involving as they do probability functions obtained by use of the newer quantum mechanics.

As the energy of a transition increases, the probability of a molecule being in the corresponding state of excitation due to thermal or other causes decreases rapidly, and the probability of Anti-Stokes terms drops off enormously. Recently, Ornstein and Rekveld [1] have used the changes in the intensity of Raman Anti-Stokes lines with temperature to check the Maxwell-Boltzmann distribution laws.

EXPERIMENTAL.

The experimental technique is as follows: The material to be studied is placed in a long tube, illuminated along its length with an arc spectrum, and the spectrum of the light scattered at right angles is recorded by a photographic spectroscope through a window in the end of the tube. With one exception, all the experimenters to date have used mercury arc excitation. The ideal working arrangement would be illumination with a single strong spectral line, and mercury is probably the most convenient and intense line spectrum source. Such single line excitation cannot be used, however,

[1] Ornstein and Rekveld, *Phys. Rev.*, **34**, 720, 1929.

without the introduction of filters, with the consequent loss of light intensity and the danger of extraneous Raman lines due to the filters.

Using the whole visible mercury spectrum, there arises the uncertainty as to which mercury line gives rise to any one Raman line. As a matter of fact it is only recently that sufficient means have been developed and used to make possible the proper identification of "excited" line with its "exciting" line. In a number of the earlier experimental articles some form of reservation has been made for the possibility that some of the excited lines may not be associated with their proper exciting lines. The introduction of filters for this process of identification has already been mentioned. Another method, which we have resorted to, is the use of excitation by two different kinds of arcs, in this case helium and mercury. If two separate exposures of the same system with these two different kinds of lamp are made coincident, characteristic frequency differences may be recognized.

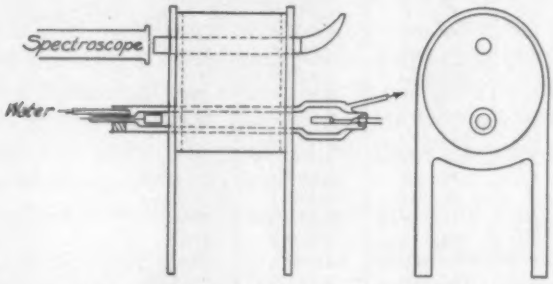
The method of obtaining the characteristic frequency differences consists in tabulating the wave numbers of the Raman lines against the wave numbers of the possible exciting lines. This having been done, a search is instituted for coincidences, since two equally strong lines should produce the same series of Raman shifts. Strong transitions are easily detected in this way, but the less probable ones are appreciable only in connection with the most intense line and very often the corroborative testimony of the second occurrence is concealed in the overexposed region near a strong incident line. The use of both mercury and helium allows at least one independent check on each wave number difference, minimizes the possibility of chance coincidence, and puts the weaker transitions on as positive a basis as the strong.

In order to make our exposures as efficient as possible an elliptical reflector was used.* This reflector, shown diagrammatically in Figure 1, consists of mathematically correct elliptical surfaces cut in relief on two heavy brass plates and a thin, silver plated sheet of brass bent to fit these end-plate

* The use of such a reflector was suggested to us by Mr. Frank Benford of this laboratory. Dadieu and Kohlrausch (*Phys. Zeitschr.*, **30**, 384, 1929) also make use of such a reflector.

shoulders, thus forming the reflecting surface. Rods through the two end plates hold the reflector in position. The end plates are bored at the exact positions of the foci, allowing

FIG. 1.



Apparatus assembled for Raman investigation.

both the arc lamp and the sample tube to be introduced and removed without interfering with the alignment. The advantage in illumination is marked. Preliminary experiments indicate that the time of exposure with the reflector is less than one-third that required when arc and sample tube are placed, open, side by side, at a distance of two inches.

It is necessary to dissipate in some way the heat generated by the arc. The helium tube was water jacketed. Air was blown through the reflector when the mercury tube was used. This lowered the mercury pressure in the lamp and cut down the luminous efficiency, thus necessitating a considerable increase in the exposure time. This difficulty can probably be overcome by the use of a vacuum jacket for the arc, with air cooling for the rest of the reflector.

Eastman astronomical green sensitive plates have proved the most satisfactory. They are at least twice as fast as the Eastman Speedway plates used previously. Using the helium arc and the green sensitive plates, pictures with forty or more Raman lines have been obtained with a four hour exposure.

As the summarized results will show, most of the present work was done with compounds containing nitrogen—specifically, nitro compounds and amines. These all have either a natural yellow color or take on this tint after exposure to strong light. This coloration acted as a light filter, often

TABLE I.

Carbon Tetrachloride-Helium Excitation.

λ.	*J.*	ν.	λ (He).	Δν.
3,850	1	25,974	3,819.8	204
3,843	5*D*	26,021	3,888.8	(−307) (Anti Stokes)
3,857	5*D*	25,927	3,888.8	(−213)
3,921	6	25,504	3,888.8	210
3,936	7	25,406	3,888.8	308
3,959	7	25,259	3,888.8	455
3,999	2*D*	25,006	3,964.9	214
4,013	4*D*	24,919	3,964.9	301
4,038	3	24,756	3,964.9	455
3,978	1	25,138	4,026.3	(−300)
3,990	2	25,062	4,026.3	(−224)
4,063	4*D*	24,612	4,026.3	226
4,078	4*D*	24,522	4,026.3	316
4,102	4	24,378	4,026.3	460
4,070	2	24,570	4,121.0	(−304)
4,160	2*D*	24,038	4,121.0	228
4,199	1*D*	23,815	4,121.0	451
4,428	4*D*	22,583	4,388.1	206 (Also 4,472, Δν = (−222))?
4,447	2	22,487	4,388.1	302
4,410	4*D*	22,676	4,471.6	(−315)
4,428	4*D*	22,583	4,471.6	(−222)
4,516	6	22,143	4,471.6	218
4,534	6	22,055	4,471.6	306
4,563	7	21,915	4,471.6	446
4,582	2	21,824	4,471.6	537
4,592	2	21,777	4,471.6	584
4,624		21,626	4,471.6	735
to	4	to		to Band
4,637		21,566		795
4,809	2*D*	20,794	4,471.6	1,567
4,664	1	21,441	4,713.3	(−224)
4,758	2*D*	21,017	4,713.3	200
4,780	2*D*	20,920	4,713.3	297
4,978	3	20,088	4,922.1	229
4,958	3	20,169	5,015.7	(−233)
5,073	5*D*	19,712	5,015.7	224
5,097	5*D*	19,619	5,015.7	317
5,133	6*D*	19,482	5,015.7	454
5,153	2	19,406	5,015.7	530
5,172	2	19,335	5,015.7	601
5,213		19,183	5,015.7	753
to	4*D*	to		to Band
5,225		19,139		797
5,676	3	17,618	5,875.9	(−600)?
5,693	3	17,565	5,875.9	(−547)?
5,718	4*D*	17,489	5,875.9	(−471)
5,766	4*D*	17,343	5,875.9	(−325)
5,796	4*D*	17,253	5,875.9	(−235)
5,942	4*D*	16,829	5,875.9	189
6,030	3*D*	16,584	5,875.9	434

causing complete opacity to light shorter than 4,500 Å. Wratten and Wainwright panchromatic plates were used for these substances. The dispersion of the spectroscope was so small in this region that the same accuracy cannot be claimed for Raman lines falling above 5,400 Å. The question of accuracy is a hard one to decide. A dispersion curve was used which was based on lines of mercury, helium and argon, instead of making a direct comparison on each plate with a copper arc spectrum or other standard source. However, since the strong lines of the exciting spectrum are always present on the plate, these serve to check the spectroscope against any change in focus or setting.

The substances whose Raman spectra were studied were:

Benzene	Para Nitrotoluene (dissolved in Carbon Tetrachloride)
Nitrobenzene	
Toluene	Carbon Tetrachloride
Ortho Nitrotoluene	Aniline
Meta Nitrotoluene	Orthochlorophenol

The work on benzene, nitrobenzene and aniline was not as complete as on the other compounds, serving merely to check the presence or absence of the strong characteristic lines of the other compounds.

Limited space prohibits the listing of the wave-lengths, exciting lines, etc., of the individual Raman lines. The results with carbon tetrachloride—helium excitation—will suffice to illustrate the number of lines obtained and the order of the agreement. In Table I the headings have their usual meaning. Under the column headed J, the intensity, a figure D indicates an apparent diffuseness in a line.

Table II summarizes the results on carbon tetrachloride. The first two columns list the weighted averages of the wave number differences of Table I and their respective probabilities. Columns III and IV list the infra red wave-lengths corresponding to $\Delta\nu$ of column I, and the position of the infra-red absorption maxima as found by Coblentz. The last two columns give for comparison the Raman results of Dadieu and Kohlrausch [2] and of Pringsheim and Rosen.[3]

[2] Dadieu and Kohlrausch, *Phys. Zeitschr.*, 30, 384, 1929.

[3] Pringsheim and Rosen, *Zeit. f. Physik*, 50, 741, 1928.

TABLE II.

Carbon Tetrachloride-Helium Excitation—48 Lines.

$\Delta\nu$.	J.	$\lambda R(\mu)$.	(Coblentz) $\lambda IR(\mu)$.	(D. & K.)[3] $\Delta\nu$.	(P. & R.)[3] $\Delta\nu$.
219	10	45.6		205	217
309	9	32.3		300	315
453	8	22.1		440	458
538	2	18.6			
594	2	16.8			
745		13.4	13.6	760	757
to	3	to	to		
796		12.6	12.3	780	793
			10.1		
			8.25		
			8.02		
			6.57		
(1567)	1	6.39	6.45		(1539)

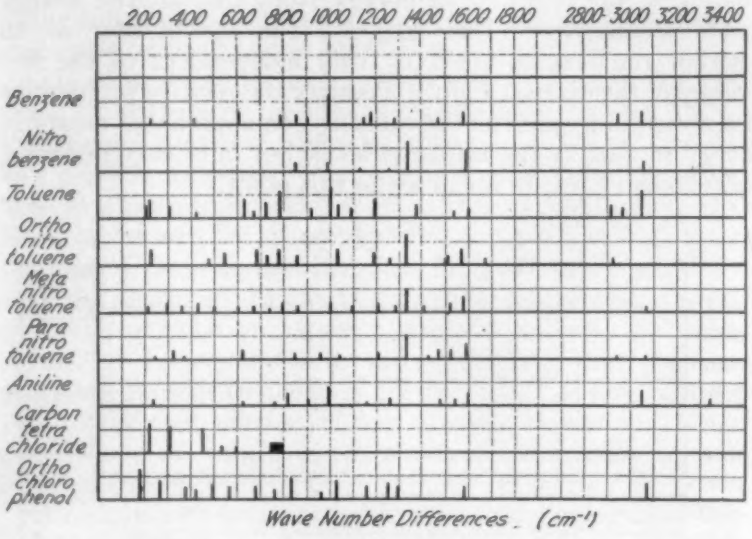
Nitrobenzene, the three nitrotoluenes and aniline darkened under illumination. Para nitrotoluene, solid at room temperatures, was dissolved in carbon tetrachloride, giving a solution of approximately 50 per cent. by weight. The aniline used, though distilled several times and almost devoid of yellow tint, darkened rapidly and gave rather poor plates. For this reason less weight is given to some of these frequencies.

The wave number differences for the substances investigated are shown graphically in Fig. 2. In order to prepare Fig. 2 the number of Raman lines used was as follows:

Substance.	No. of Lines.
Benzene	37
Toluene	98
Nitrobenzene	19
Ortho Nitrotoluene	71
Meta Nitrotoluene	82
Para Nitrotoluene (in solution)	93
Aniline	43
Ortho Chlorophenol	109

The chemicals used were obtained from the Eastman Kodak Company, and were described by them as being of highest purity, with the exception of the meta nitrotoluene which was of the "technical" purity. The latter was fractionally distilled and the fraction taken boiled within a 0.5° C. range.

FIG. 2.



Strong scattered frequencies from several organic liquids.

DISCUSSION.

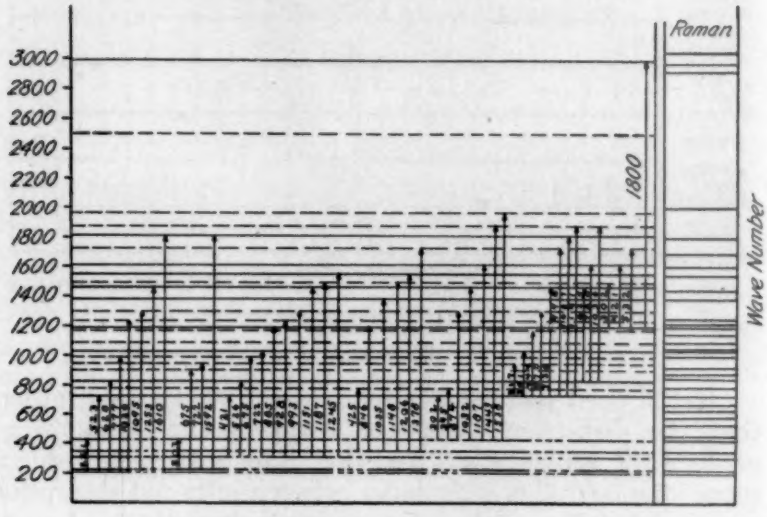
It has been pointed out by Langer,[4] Dieke,[5] and others that the dispersion theory of Kramers and Heisenberg [6] predicts the Raman effect and that Raman frequency differences may be due to differences between infra-red absorption energies as well as to the infra-red levels themselves. Langer gives a form of Grotrian diagram for carbon tetrachloride in which the energies corresponding to the measured infra-red bands form the discrete energy states.

Examination of our data for toluene shows that roughly one-half of the energy differences found correspond (within 1 per cent.) to positions of infra-red absorption maxima found by Coblentz, that is in the range up to 15 μ. The infra-red maxima found by Coblentz and others are all possible excited states of the molecule. The fact that all of these do not give rise to corresponding Raman transitions indicates that only

[4] Langer, *Nature*, 123, 345, 1929.
[5] Dieke, *Nature*, 123, 564, 1929.
[6] Kramers and Heisenberg, *Zeit. f. Physik.*, 31, 681, 1925.

certain of these states are capable of interacting with light quanta so far removed in energy from that of the energy states themselves. This suggests the speculation as to whether the Raman effect is truly independent of the frequency of the exciting light. Possibly the relative probability of a transition varies as the exciting line approaches nearer in energy to that of the infra-red level, but only very intensive and extensive research can settle this point.

FIG. 3.



The molecular energy levels of toluene.

Those infra-red energies which coincide with Raman frequencies are taken as the starting point in the present analysis, since their occurrence proves that an appreciable number of molecules do exist in these excited states. In Fig. 3 these energy levels are shown by solid horizontal lines. The dotted horizontal lines show the other possible energy states. According to Langer, transitions from one energy state to another are possible if both states arise from possible transitions from a third common level of lower energy content. Since all the measured infra-red levels are reached by single excitation from the normal unexcited state of the molecule, they all satisfy this condition and therefore transitions

between any two of them are allowed. The first and most important limitation to their occurrence lies in the number of molecules existing in the lower of the two states.

By subtracting the energy values of the basic states (solid lines) from those of the other possible levels (dotted lines) of higher energy content, there is obtained a list of the theoretically possible quantized energy bundles which the molecule is able to absorb from incident radiation. Examination of the afore-mentioned list of energy differences shows that a large number of them agree within the limit of experimental error with the measured Raman frequencies. Moreover, a number of these particular values seem to appear not once, but several times. It is impossible to state definitely that the corresponding Raman frequencies are the result of any particular one, or for that matter, of any of these transitions, but the coincidence of values seems to have more than a chance significance.

Coblentz, whose infra-red investigations cover the widest range of compounds, limited his measurements to the range between 1 and 15 μ. There is no reason to believe that the rotation-vibration bands are limited to this region, so for most compounds we have no way of checking our Raman frequencies of less than 700 cm^{-1}. Assuming the stronger of these lower values to correspond to absorption levels farther out in the infra-red and applying the same reasoning, different values are obtained which serve to account for several more measured Raman lines.

Table III summarizes the result of these rather involved and circuitous calculations for toluene. Columns I and II give Raman frequencies and intensities, and column III those infra-red frequencies which correspond and serve as base levels for higher transitions. The succeeding columns list the frequency differences resulting from transitions from the base levels which head the respective columns. It will be noted that several important Raman lines remain unexplained, notably the last one of 3,051 cm^{-1}.

Benzene and aniline have been subjected to this analytical treatment with approximately the same degree of success. The task of unravelling the mass of Raman data is an arduous but an important one. The most striking anomaly is the

TABLE III.

Toluene.

Raman Δν.	J.	Infra-Red (Coblentz) ν.	Basic Levels								
			203.	221.	305.	344.	424.	726.	831.	1190.	1379.
203	4			203							
221	6		221					217			
305	4						302	301		302	
344	1						345				343
424	2				421	425				421	
448	1							444			
527	3		523		526					532	
579	1							572			583
625	6		628						625	623	
671	2			675	675					677	
727	5	726		722	722			730			
		769									
785	9		777						780		
840	3	831				846					
878	1		875		885		874				
		896									
920	3				928						
		943									
		980									
1,001	10				993			996			
1,034	4	1,027	1,030			1,035	1,032		1,036		
1,052	1										
		1,078									
1,094	3		1,095					1,087			
1,147	2				1,151	1,148		1,141			
		1,170									
1,194	6	1,190			1,187		1,187				
1,218	3					1,206					
		1,233									
1,252	1		1,253		1,245						
		1,298									
1,377	4	1,379				1,378					
1,442	2	1,456					1,443				
		1,492									
1,540	2	1,550					1,538				
1,600	3	1,611	1,610	1,592							1,611
1,685	1										
		1,722									
1,796	1	1,813								1,800	
		1,867									
		1,962									
1,996	1										
		2,500									
2,917	4										
2,969	3	2,990							2,960		
3,051	9										
		4,150									
		4,580									
		5,850									

peculiar choice of the infra-red absorption bands which give rise directly to Raman lines. In a large number of cases, they are the very weak rather than the strong ones. This indicates some fundamental distinction between the rotation-vibration frequencies, hitherto unremarked. The existence of integral multiples of frequency values was pointed out long ago and attributed to fundamental and harmonic vibrational frequencies. In the present anomaly this may be an important factor. It is clear that a complete solution of this problem of Raman spectra will involve also the solution of the origin and nature of the near infra-red spectra and a clearer insight into the structural linkages in polyatomic molecules.

The purpose of this investigation was stated as an attempt to discover in Raman lines a key to the linkages between atoms and to develop a tool for the investigation of complex substances of known components but unknown structure. The key is there, undoubtedly, just as it was always in the data on infra-red absorption. Possibly, due to the much greater ease of spectroscopic research in the visible region, the Raman effect will eventually lead to the unravelling of interatomic linkage. However, there are a number of difficulties to be overcome. We mention two which must be considered.

First, the large number of characteristic frequencies attributable to even the simplest compounds makes coincidence, overlapping, and the like very serious sources of error. The chief frequency difference for any compound is generally unmistakable, but this most important clue is just as likely to be characteristic of the radical of the substituted molecule (e.g., the benzene ring) as of the substituted atom (e.g., the chlorine in monochlorobenzene). In determining the exact structure of an unknown, the more important evidence lies in the weaker lines, where identification is more difficult.

Second, substitution in a compound does not simply add new lines, characteristic of the new linkage, but may bring about almost total suppression of one of the strongest lines of the unsubstituted radical, or more confusing, a shift, of apparently indeterminate direction and magnitude. As a notable example, let us consider the three nitrotoluenes. The

line shifted through 1,000 cm^{-1}. is the most prominent in benzene and toluene. In nitrobenzene and aniline it is quite strong. In ortho and para nitrotoluene it does not occur, or else it is the shifted line at 1,030–1,040 cm^{-1}. In the meta nitrotoluene it falls exactly at 1,000 cm^{-1}. The same positional influence is shown for this frequency in the article of Dadieu and Kohlrausch,[2] for the three xylenes. This illustrates the complexity of the task of measuring the wavelength of lines and from them deducing the existence of certain structures.

It may be stated, however, that Raman frequencies attributable to linkages to externally substituted atoms or groups seem to be relatively undisturbed by positional effects. A line corresponding to approximately 1,335 cm^{-1}. was found to be the strongest for nitrobenzene and for all the nitrotoluenes. It was lacking in benzene and toluene, and also in aniline. This indicates its origin in a nitrogen to oxygen linkage, since the carbon to nitrogen should be present in aniline. This represents definite progress with the task at hand.

SUMMARY.

An attempt is made to discover in the molecular scattering of light a method by which atomic linkages in molecules may be recognized. The essential features of the method are described. There are rather serious difficulties in its application to complex molecules, two of which are suggested. Nevertheless, it may be claimed that the work is not without result, because frequencies attributable to linkages which hold externally substituted atoms or groups seem to be relatively undisturbed by positional effects.

In conclusion, the authors wish to express their indebtedness to Mr. G. M. J. Mackay whose interest in this problem made the present work possible.

SCHENECTADY, N. Y.,
February 10, 1930.

CHARACTERISTICS OF BELL VIBRATIONS.

BY

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A bell is a metallic structure designed for the production of sound of a pleasing quality. The quality depends upon the relative amplitudes and frequencies of the series of tones of the bell, which in turn depend on its shape and thickness. Most bells are essentially a cylinder with one end closed by a flat plate and with a flared out portion at the other end. The closed end is called the crown and the open end, where the thickness is considerably increased, is called the sound bow.

Considering the bell as a modified cylinder or as a curved shell, it is to be expected that its flexural vibrations would be characterized by nodal lines, which are equidistant meridians, and by parallel circles of latitude. The crown is of course a circular node for all vibrations. For this class of vibrations the number of meridian nodes cannot be less than four, and must be even, but there can be any number of circular nodes. In this paper a vibration will be designated by two numbers; the first, its number of meridian nodes; and the second, its number of circular nodes. Thus a 6–3 has six meridian nodes and three circular nodes, excluding the node at the crown.

In addition to the above form of vibration, two other types are possible; the first, an expansion and contraction without deformation of the circular shape, having any number of circular nodes; and the second, a vibration which resembles the compressional or longitudinal vibrations of a rod with two meridian lines of no radial motion. The frequencies of all of these vibrations can be calculated for certain vibrating systems, such as a cylinder or a flat plate, but for an irregular shape like a bell this calculation is impossible.

In the sound of a bell distinct beats can often be heard in one or more of the partials. According to Lord Rayleigh this is due to lack of symmetry in the bell. The same effect can be

produced by applying a load to the bell. If the system of meridian nodes is located so that this load is at an antinode, the frequency of the tone will be slightly lower than if the load is at a node. When the bell is struck at a node for either one of these tones, the other is excited alone, but when the blow is struck at any other point, both tones are excited simultaneously and beats are heard.

This phenomenon of beats was used by Lord Rayleigh in his investigation of bell tones. In his method the bell is tapped at various points around the circumference and the tone in question is selected by the use of Helmholtz resonators. Due to a local load fastened to the bell or to its natural lack of symmetry, beats are produced. If the point of excitation is moved around the circumference these beats will disappear for a number of points equal to double the number of meridian nodes. The circular nodes are found by tapping the bell along a meridian, and noting the points at which the intensity for the tone in question is a minimum.

Another method of investigating bells is that used by A. B. Simpson, in which the stem of a tuning fork is held in contact with the bell at different points. If the frequency of the fork coincides with one of the partials of the bell, a tone will be produced, the loudness depending on the location of the point of contact. This gives a method for finding circular nodes, but for the location of meridian nodes the bell must be restrained at one or more points while the fork is moved around the circumference to determine the number of points of least sound excitation.

Professor A. T. Jones in his work on bell vibrations, has used a resonator connected by a rubber tube to a stethoscope with which he listened to the sound coming from different parts of the bell, which is always struck at the same spot.

All of these methods depend on observations made on a sound which is constantly diminishing, and are therefore somewhat uncertain. Simpson's method is limited by the necessity of using a tuning fork of the same frequency as the tone. The methods in which the bell is excited by tapping are open to objection because of the difficulty of picking out one tone from the great number produced, even with the use of a resonator. This is especially true when working with high

frequencies. Besides this difficulty, Jones' method of listening to the sound in the air is made very uncertain by the interference with the sound from other parts of the bell. This is especially confusing when working in a room where standing waves are present.

In order to increase the range of tones to be investigated, and to get more certain and easily obtained results, the excitation should be continuous, it should excite one frequency at a time, and it should not change the frequencies of the free bell tones by loading or otherwise. In regard to the detection of the motion of the bell, the best results should be obtained by using a device which responds to the motion of the bell itself, and to motion in one direction only, as the nodes for radial motion are antinodes for tangential motion.

The tone was excited in these experiments by means of a vacuum tube oscillator, the current from which passed through an ear-phone whose pole pieces rested on a small piece of rubber covered iron in contact with the bell. The frequency of the oscillator was varied until it coincided with one of the partials of the bell; this condition being indicated by a sound maximum. To make sure that the frequency thus found was the same as that excited by tapping, a tuning fork was loaded until it gave a certain number of beats per second with the oscillator tone, and then the number of beats was counted when the tone was produced by tapping. The number of beats was found to be the same except in the case of the smallest bell tested, and even here the difference was removed by supporting the excitor so that its weight was not an appreciable load on the bell.

The first instrument used in this test to observe the motion of the bell was the pickup of a phonograph connected to the ears by rubber tubes. In this device the motion of a pin is transmitted by a lever to a diaphragm which varies the air pressure in a small cavity behind it, producing sound. This was quite sensitive, but since one side of the diaphragm was open to the air, confusing phase differences between the air vibrations and those of the bell were produced, depending upon the way the diaphragm faced. Another disadvantage was, that it responded to motion of the pin in two directions. These defects were removed in an instrument devised by Mr.

B. E. Eisenhour, of the Riverbank Laboratories. In this pickup the motion of the bell in one selected direction is transmitted to an entirely enclosed diaphragm, and the sound from the cavity behind the diaphragm carried to the ears by tubes, as before.

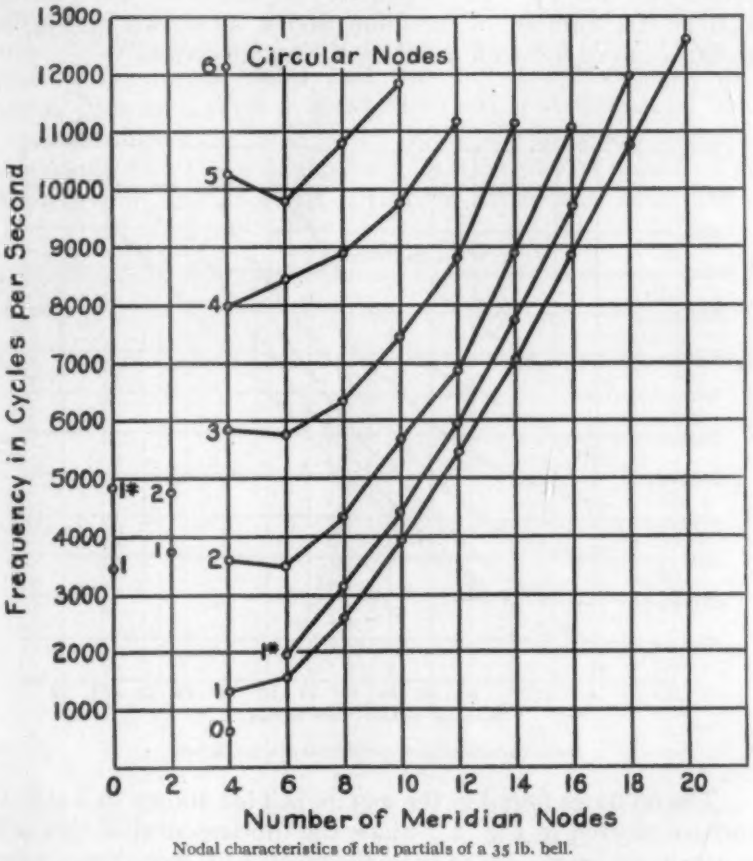
The instrument was checked for sensitivity by holding it in contact with the stem of a tuning fork, and by this means the fork could be heard even after the sound from the prongs was inaudible when held to the ear. For certain frequencies it was found that the response was cut down by resonance effects in the tubes carrying the sound to the ears. Different lengths of tubes were used for these ranges of frequencies, which were located by testing the instrument with a set of tuning forks.

The procedure of finding and classifying the vibrations was as follows: the excitor was placed in contact with the bell, and the frequency of the oscillator continuously changed until the bell was heard to respond, either directly by ear or by the use of the listening instrument. The number of meridian and circular nodes was then found by exploration over the surface of the bell with the listening device, and the frequency was determined by comparison with a set of tuning forks covering the range between 512 and 4,096 D.V. To determine frequencies higher than 4,096, a second oscillator was tuned to a known multiple of the frequency of a fork and the difference tone between this frequency and the one in question was determined by the use of the set of forks. With this arrangement it was easy to determine frequencies up to 13,000 cycles per second, which was the limit of the investigation. Frequencies below 512 were found by comparing the harmonics of the oscillator with the set of forks.

All the tones presented in the results were not discovered the first time the range of frequencies was traversed, but when the results of the first run were plotted as frequency against number of nodes, the regular series of curves obtained gave an indication of the frequencies of the missing tones. The fact that some tones were missed in the first run is due to the quite considerable differences in loudness, and to the possibility of two occurring at very nearly the same frequency. In this latter case, the two might be mistaken for one form of vibration with a slightly different position of the nodal pattern, due

to lack of symmetry in the vibrating system, as explained above. By moving the excitor around the circumference, one of the pair may be made to disappear for a number of points equal to the number of meridian nodes, thus checking the

FIG. 1.



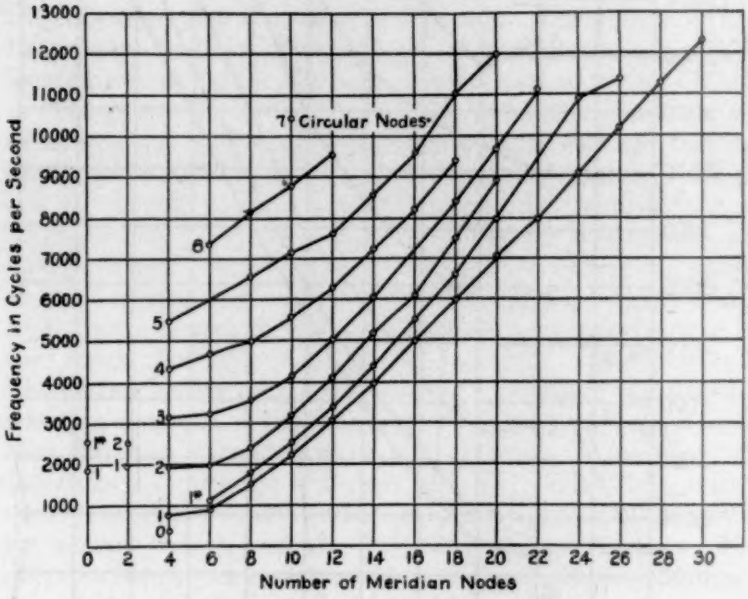
Nodal characteristics of the partials of a 35 lb. bell.

explanation of beats given by Lord Rayleigh. When the bell manufacturers pick out a certain point at which the bell is to be struck, it is in the effort to avoid beats by exciting only one of the two tones which would produce the most objectionable interference.

Three bells of different sizes were investigated, and the

tones found are presented in the form of a table. The weights of the bells were: 800, 250, and 35 lbs., and the frequencies of the hum tones were *C*-259 *F*♯ 367, and *E*♭ 650, respectively. The most complete set of partials was found for the 35 lb. bell, which gave 44 tones below the frequency limit, 13,000 cycles per second. The frequency of the tone was plotted against the number of meridian nodes, as shown in Fig. 1, giving a curve for each number of circular nodes.

FIG. 2.



Nodal characteristics of the partials of a 250 lb. bell.

The 68 tones found in the 250 lb. bell are shown in Table 1, and are plotted in Fig. 2. Since the fundamental of this bell is nearly an octave lower than the small bell, more tones were found, involving larger numbers of circular and meridian nodes, before the frequency limit was reached, but the series of tones are not as complete. The largest number of meridian nodes was 30, while 7 circular nodes were found.

The work on the 800 lb. bell was carried only far enough to be sure that the series of tones was similar to those of the two

smaller bells. The results from this bell are also shown in Table 1.

An interesting series of tones was found in which a circular node was located at the sound bow very close to the rim. To distinguish this from the tone having a circular node between the sound bow and the crown, its number of circular nodes will be designated as 1#. The motion of the bell for this 1# tone is maximum about half way between the crown and sound bow, and there is almost no motion at the sound bow. This position of the node is due to the inertia concentrated at the sound bow. An analogous vibration can be produced by holding one end of a flat spring in a vise and attaching a

TABLE 1.

Tone.	Meridian Nodes.	Circular Nodes.	Frequency 250 lb. Bell.	Frequency 35 lb. Bell.	Frequency 800 lb. Bell.
1	4	0	367 D.V.	647 D.V.	269 D.V.
2	4	1	731	1,304	517
3	6	1	861	1,552	622
4	6	1#	1,093	1,968	830
5	8	1	1,468	2,596	1,034
6	8	1#	1,766	3,120	
7	0	1	1,850	3,430	1,308
8	4	2	1,915	3,588	1,404
9	6	2	1,934	3,482	1,413
10	2	1	1,952	3,734	1,487
11	10	1	2,200	3,920	1,540
12	8	2	2,384	4,304	1,796
13	10	1#	2,500	4,388	2,064
14	2	2	2,522	4,635	
15	0	1#	2,592	4,816	2,495
16	12	1	3,024	5,440	2,112
17	4	3	3,136	5,824	2,181
18	10	2	3,168	5,680	2,414
19	6	3	3,200	5,752	2,320
20	12	1#	3,368	5,926	2,830
21	8	3	3,580	6,312	2,620
22	14	1	3,936	7,078	2,752
23	12	2	4,096	6,848	3,140
24	10	3	4,160	7,424	3,111
25	4	4	4,316	7,974	
26	14	1#	4,381	7,712	3,688
27	6	4	4,690	8,432	
28	16	1	4,928	8,848	3,430
29	8	4	4,968	8,896	3,621
30	12	3	4,992	8,800	3,780
31	14	2	5,136	8,880	
32	4	5	5,450	10,272	
33	16	1#	5,472	9,696	
34	10	4	5,504	9,744	4,072
35	6	5		9,792	

TABLE I.—*Continued.*

Tone.	Meridian Nodes.	Circular Nodes.	Frequency 250 lb. Bell.	Frequency 35 lb. Bell.	Frequency 800 lb. Bell.
36	18	1	5,942	10,720	4,126
37	14	3	6,009	11,120	
38	16	2	6,016	11,072	
39	12	4	6 246	11,158	4,672
40	8	5	6,528	10,800	
41	18	1#	6,594	11,936	
42	20	1	7,024	12,592	
43	10	5	7,120	11,840	
44	4	6		12,160	
45	14	4	7,200		
46	6	6	7,332		
47	18	2	7,488		
48	12	5	7,597		
49	22	1	7,936		
50	20	1#	7,978		
51	8	6	8,120		
52	16	4	8,186		
53	18	3	8,381		
54	14	5	8,510		
55	10	6	8,736		
56	20	2	8,880		
57	24	1	9,040		
58	18	4	9,376		
59	12	6	9,504		
60	16	5	9,568		
61	20	3	9,648		
62	26	1	10,144		
63	10	7	10,400		
64	24	1#	10,830		
65	18	5	11,008		
66	22	3	11,072		
67	28	1	11,232		
68	26	2	11,332		
69	20	5	11,968		
70	30	1	12,238		

weight to the other end. When the spring is struck a sharp blow, it will vibrate transversely without moving the weight, except for a slight motion perpendicular to the motion of the spring. This system of circular nodes was found for each number of meridian nodes from six up. There seems to be no reason why a 4–1# should not occur, but it could not be found in any of the bells tested.

Two tones were found in each bell consisting of expansion and contraction without deformation of the circular shape. The number of circular nodes was 1 and 1#. This form of vibration was not found for larger numbers of circular nodes, and there was no way to tell just where to look for the more

complicated forms, as it did not follow the same sort of a curve as the vibrations having meridian nodes.

Two tones, having two meridian nodes, were found in each bell, a 2–1 and a 2–1♯. The two meridians, are merely lines of no radial motion, as the radial component of the motion on either side of the line is in the same direction. On investigating the direction of the motion, it was found that it was not radial as in all the other tones, but all parts moved parallel to each other, perpendicular to a plane passed through the two meridian lines. This is different from the transverse vibration where a deformation of the circular shape would produce a minimum of four meridian nodes.

In every case except three, the frequencies increased with the number of meridian nodes for a given number of circular nodes. These exceptions occurred in the 35 lb. bell where the 4–2, 4–3 and 4–5 had higher frequencies than the 6–2, 6–3, and 6–5, respectively. These reversals can be explained by the fact that the circular nodes did not remain in the same place as the number of meridian nodes was increased. Thus the shifting of the position of a given number of circular nodes in the unequal cross-section of the bell, counteracted the frequency rise that would be expected from an increase in the number of meridian nodes. In all cases the rise of frequency as the number of nodes increased from four to six, was small.

The simplest form of vibration with no circular nodes was found only with four meridian nodes. Excluding this series, it can be seen, by referring to the curves, that the 47 partials below 12,000 D.V. found in the 35 lb. bell are complete except for one tone, the 4–1♯, not found in any bell.

The results, here given, agree with those of Lord Rayleigh for the first five partials, except that he did not find any circular node for the fourth partial which is located at the sound bow. He noticed, however, that this tone was best excited by tapping the middle part of the bell. A. T. Jones found the number of meridian nodes for ten partials, and the number of circular nodes for the first seven of these. A comparison of these results is made in Table 2. It is believed that the improved apparatus used and the completeness of the series of tones found justify confidence in the results presented.

TABLE 2.

Comparison of the Lower Partials with Those Found by Other Investigators.

	Lord Rayleigh.	A. T. Jones.	This Investigation.
1	4–0	4–0	4–0
2	4–1	4–1	4–1
3	6–1	6–0	6–1
4	6–?	6–1	6–1#
5	8–1	8–1	8–1
6		8–2	8–1#
7			0–1
8			4–2
9			6–2
10			2–1
11		10–2	10–1
12		8–?	8–2
13		10–?	10–1#
14			2–2
15			0–1#
16		12–?	12–1

No attempt was made to provide a formula for the curves of frequency plotted against the number of circular nodes, as the shape of a bell is so irregular and bells made by different manufacturers do not, in general, have the same shape. Calculations of the frequency of the tones having two meridians were made by assuming that they were the same as the compressional waves in a rod with a length equal to one-half the circumference of the bell at the soundbow. For the 35 lb. and the 250 lb. bell the frequencies as calculated were 3,660 and 1,830 D.V. and as measured in the 2–1 form they were 3,734 and 1,952 D.V. respectively. This calculation does not take into account the varying diameter of the bell, the presence of a circular node, or the fact that the vibrating segment is not straight but curved.

In locating tones it was found useful to plot frequency against the number of circular nodes, as well as against the number of meridian nodes, as in the curves presented. This gave a set of curves one for each number of meridian nodes, but is not an independent way of plotting the results.

The quality of a bell is commonly regarded as being determined by the relative frequencies of the first five partials. These are supposed to be according to the ratios 1–2–2.4–3–4, or in musical terms; a fundamental or hum note, its octave, a

minor third, a perfect fifth, and the next octave. Thus the musical notes corresponding to the first five partials of a *C* bell are: C_1, C_2, E_{b2}, G_2, C_3. Some writers extend this to seven tones, including a major third and a perfect fifth in the next octave.

The better bell manufacturers produce the proper relationship of these five tones by design of the bell casting, and by grinding or turning the bell at different places. It is difficult to avoid some grinding, since, even when casting two bells of the same size, a slight difference in the composition of the metal or in the rate of cooling would prevent duplication. Tuning is rather a difficult process as the five tones are interrelated, and work must be done in certain regions where some tones are affected more than others. The tuning is done by the removal of metal in certain relations to the positions of the circular nodes, and is possible because they are located at different points in the bell.

It is considered difficult to make small bells with a pleasing tone. This is probably due to the difference tones between the partials, and to beats, both of which are more pronounced in the high frequency bells. Since the tones are in the ratios 1–2–2.4–3–4, the difference tones between the second, fourth, and fifth tones should be the same pitch, and if any of these are a little off pitch, beats will be produced. Low frequency difference tones also give more trouble in small bells since the difference tone between two tones above 2,500 D.V. usually seems louder than the primary tones.

There has been considerable discussion about the pitch and character of the so-called strike tone of a bell. When a bell is struck, a complex sound is produced which gives the sensation of a certain pitch. This predominating pitch is called the strike or striking tone. Professor Jones gives it as the octave below the fifth tone, and regards its origin as something of a mystery. In the bells here investigated the pitch seemed to be the same as the second partial, which was not far from being an octave below the fifth partial. In such a complex sound where the various components are dying out at different rates, it is hard to judge what tone or combination of tones predominates.

In conclusion I wish to express my appreciation of the

assistance rendered by the staff of the Riverbank Laboratories, especially to Mr. B. E. Eisenhour whose many valuable suggestions and improved listening device were very helpful in the investigation.

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THE SCATTERING OF LIGHT BY DIELECTRICS OF SMALL PARTICLE SIZE.*

BY

G. F. A. STUTZ, Ph.D.

The diffusion of light by a cloud or suspension of relatively small particles of material may be due to:

1. Rayleigh scattering.
2. Reflection and refraction.
3. A combination of (1) and (2).

This paper presents the results of a study of the diffusion of light by a dielectric material (zinc oxide) in the range of particle sizes where, with increasing particle size, Rayleigh scattering rapidly diminishes while reflection and refraction effects become more and more important.

RAYLEIGH SCATTERING.

The theory of the scattering of light by small particles was first given by Lord Rayleigh.[1] Considering the case of a single particle of infinitesimal size compared with the wave-length of light, each particle acts as an oscillator undergoing forced vibrations of a certain amplitude in the direction of the impressed force. The particle, therefore, sends out waves whose vibrations are perpendicular to the direction of the incident light. The intensity of this scattered light is calculated by Rayleigh to be $I_s = \frac{Kd^6}{\lambda^4}$

Where K is a constant,

d = diameter of the particle,
λ = wave-length of light.

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* A Dissertation Submitted to the Johns Hopkins University in Conformity with the Requirements for the Degree of Doctor of Philosophy.

[1] "On the Blue Light from the Sky, Its Polarization and Colour," J. W. Strutt, *Phil. Mag.*, 41, 107 (1871).

Thus the intensity varies inversely as the fourth power of the wave-length of light and directly as the sixth power of the diameter of the particle. Moreover Rayleigh finds that at an angle of 90° from the direction of propagation of the light, the scattered light will be completely plane polarized.

REFLECTION AND REFRACTION.

In the case of particles large compared with the wave-length of light, the diffused light is due to reflection at the surfaces of the particle. In the case of a dielectric, this reflected light is almost independent of the wave-length (the change in refractive index with change in wave-length affects it slightly) and is proportional to the surface of the particle, thus $I_s = Kd^2$. No complete polarization is to be expected as in the case of the Rayleigh scattering. In considering particles of increasing size, a transition range must, therefore, be present between the very small, Rayleigh particles, where $I_s = \frac{Kd^6}{\lambda^4}$, the scattered light being polarized, and the large particles where $I_s = Kd^2$, with little or no polarization of the scattered light.

The more exact theoretical study of the intensity and polarization of the diffused light has been carried on by several investigators.[2] Shoulejkin,[3] following the method of Mie, calculates that Rayleigh's formula holds for particles of diameter less than one-third the wave-length of light. For particles equal in diameter to the wave-length of light he calculates that the brightness of the light scattered in the direction of the incident beam is eleven times greater than the brightness in the opposite direction, and the maximum of polarization is displaced from 90° in the direction of the incident rays. For sizes greater than this, reflection only takes place.

According to Rayleigh's formula, the distribution of the light scattered in different directions is symmetrical about an axis perpendicular to the direction of propagation of the light.

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[2] Mie, *Ann. d. Phys.*, **25**, 377 (1908). Debye, *Math. Ann.*, 67, 540 (1909). Bromwich, *Roy. Soc. London* (A) **220**, 175 (1920). Schirmann, *Ann. d. Phys.*, 59, 493 (1919). Gans, *Ann. d. Phys.*, **62**, 331 (1920); **76**, 29 (1925).

[3] *Phil. Mag.*, 48, 308 (1924).

This distribution becomes asymmetrical with increasing particle size, more light being scattered forward than backward, and Shoulejkin's calculations give the distribution, both of the total light and the polarized component for two particle sizes. H. Blumer [4] has made a more elaborate and exact series of calculations, extending the work of Rayleigh, Mie, and Shoulejkin, and has determined the distribution of intensity of both the polarized and nonpolarized components of the scattered light for a large range of particle sizes as well as for several indices of refraction in the case of dielectric particles.

Recently, Pokrowski [5] has described the "Opoloskop," an instrument for measuring the intensity of the light scattered at different angles by a suspension. He points out that by the use of Blumer's calculations, his instrument may be used to measure particle size. No actual measurements are given.

PREVIOUS INVESTIGATIONS.

Rayleigh's theory has received many experimental verifications (Crova,[6] Zettwick [7]). Mechlenburg [8] finds that in the case of sulfur, Rayleigh's formula holds for particles less than .100 micron in diameter; at .150 micron a transition begins which extends then from .250 micron to .850 micron; above .850 micron conditions again change but no relation is given. Between .250 micron and .850 micron, Mechlenburg finds that I is proportional to $1/\lambda^2$.

Bechhold and Hebler [9] in measurements of the intensity of the Tyndall beam have a maximum intensity in the case of barium sulfate in water at .800 micron and consider that for particle sizes less than this Rayleigh's law holds. Later work by Owe [10] in the same laboratory placed the maximum at about .2 micron.

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[4] *Zeit. Physik*, **32**, 119 (1925); **38**, 304 (1926).
[5] *Koll. Zeit.*, **47**, 55 (1929).
[6] *Am. Chim. Phys.*, **20**, 480 (1890); **25**, 534 (1892).
[7] *Phil. Mag.*, **4**, 199 (1902).
[8] *Koll. Zeit.*, **16**, 97 (1915).
[9] *Koll. Zeit.*, **31**, 70 (1922).
[10] *Koll. Zeit.*, **32**, 73 (1923).

MATERIALS STUDIED.

Zinc oxide is a white powder of exceptionally uniform particle size, made by the burning of zinc vapor with air. The oxide, being a fume product, is readily dispersed in water with the aid of saponin and gum arabic. Such suspensions are very stable, there is no growth of the particles on aging, and the high refractive index of zinc oxide, 2.01, makes it an ideal material from the standpoint of the amount of light it diffuses. The particular group of samples used includes several commercial samples and several that were specially prepared. The particle size of samples Nos. 5, 6 and 7 was measured by the photomicrographic method of Green,[11] while Nos. 1, 2, 3 and 4 were measured by the Stutz-Pfund turbidimeter.[12] This instrument was calibrated in this range of particle sizes by both the method of Green and the count method using a dark ground illuminator and counting chamber. The particle size figures are probably accurate to within five per cent. The samples have been selected as being the most uniform in particle size obtainable.

TABLE NO. 1.

Sample No.	Particle Size in Microns.
1	.135
2	.192
3	.217
4	.282
5	.409
6	.676
7	1.23

EXPERIMENTAL WORK ON TURBIDITY.

For the accurate measurement of the average particle size of a material in suspension the Stutz-Pfund turbidimeter has been very successful in the range from .1 to 1.0 micron. This instrument records the amount of light transmitted by a suspension of the material contained in a cell three inches long, fitted with glass windows. A diagram of the instrument is shown in Fig. 1. The amount of parallel light from lamp L_1

[11] JOUR. FRANK. INST., 192, 637 (1921).
[12] *J. Ind. Eng. Chem.*, 19, p. 51 (1927).

transmitted by the suspension in cell F is measured by means of the photometer device consisting of an optical pyrometer lamp L_2 with variable resistance and milliammeter E. The photometer device is readily calibrated by means of a rotating sector.

This instrument has been used to determine, in the case of zinc oxide suspended in water, the particle size at which

FIG. 1.

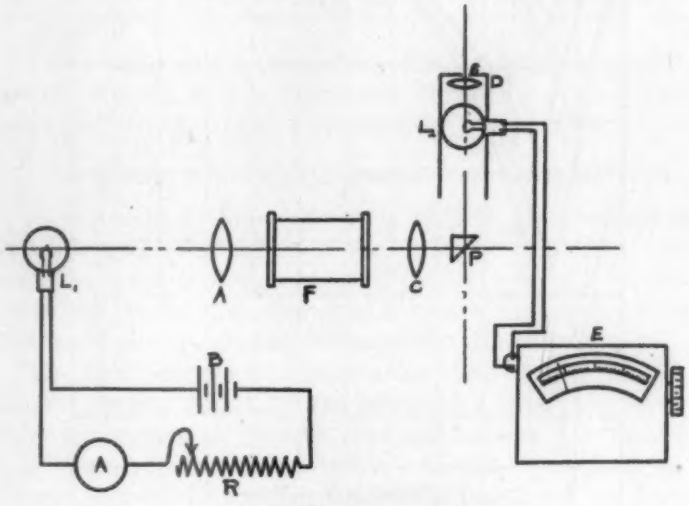
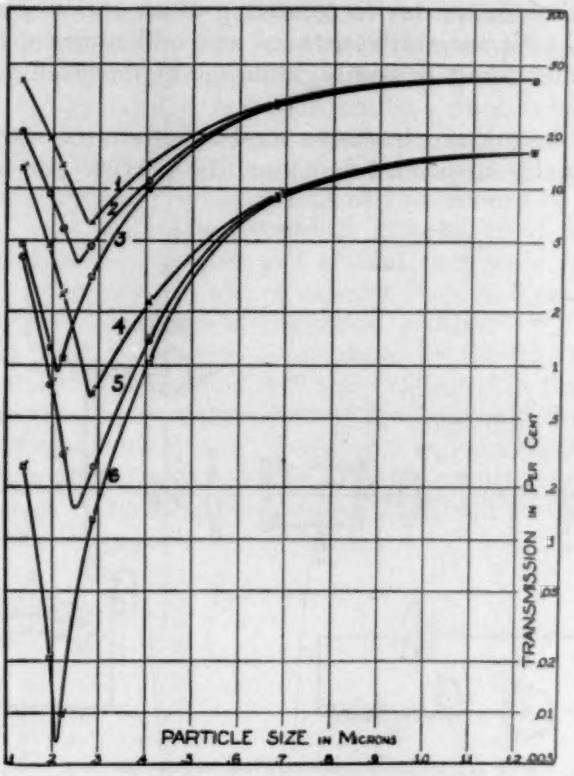


Diagram of the Stutz-Pfund turbidimeter.

the turbidity becomes a maximum (minimum transmission). In addition, the effect of the wave-length of the light used, as well as the effect of the concentration of the suspension has been studied.

For this purpose, suspensions of the samples listed in Table No. 1 were examined at two different concentrations and three glass color screens having fairly narrow spectral transmission bands were used in the photometer eyepiece. The dominant wave-length of transmission of these screens occurred at 6300 Å (red), 5500 Å (green), and 4800 Å. (blue).

FIG. 2.



Curve 1—Concentration 2.77×10^{-5} gr. per cc. wave-length = 6300 Å.
Curve 2— " 2.77×10^{-5} " " " " " = 5500 Å.
Curve 3— " 2.77×10^{-5} " " " " " = 4800 Å.
Curve 4— " 5.54×10^{-5} " " " " " = 6300 Å.
Curve 5— " 5.54×10^{-5} " " " " " = 5500 Å.
Curve 6— " 5.54×10^{-5} " " " " " = 4800 Å.

Variation in transmission with particle size.

The results are shown in Fig. 2. From these results the following conclusions may be drawn:

1. Above one micron in particle size, the suspension transmits all wave-lengths of light equally. This indicates that in the range of particle sizes from one micron up, Rayleigh scattering is negligible. This is in agreement with the work of Tolman and his co-workers, and of Bechhold and Hebler.

2. Within the range studied the turbidity maximum is independent of concentration.

3. Turbidity maxima may be tabulated as follows:

TABLE NO. 2.

Particle Size of Maximum.	Relative Particle Size.	Wave-length.	Relative Wave-length.
.21	1	4800	1
.25	1.19	5500	1.15
.275	1.31	6300	1.31

Therefore, within the range of wave-lengths studied, the particle size at which maximum turbidity occurs varies in direct proportion to the wave-length.

EXPERIMENTAL WORK ON DISTRIBUTION OF SCATTERED LIGHT.

Experimental determinations of the distribution of the intensity and polarization of the scattered light have not been extensively carried on. Most of the data recorded have been limited to the light scattered at a ninety degree angle, largely because of the apparatus difficulties involved.

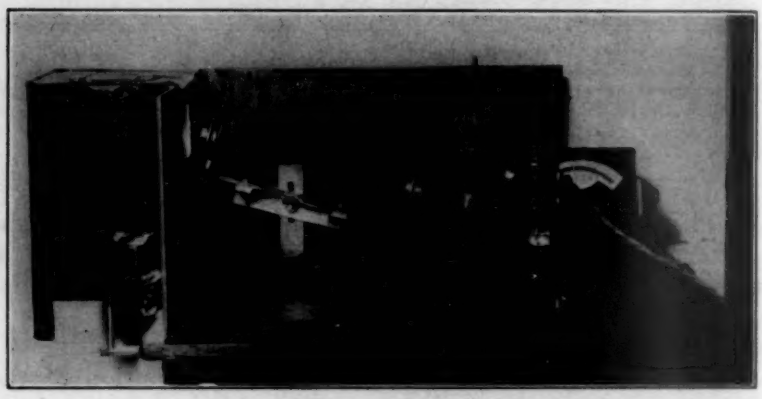
The calculations of the angular distribution of the light diffused by fine materials are based on a single particle, while any experimental determination must be based on a suspension of a large number of particles. Measurements on a large volume of a fairly concentrated suspension are very unsatisfactory due to the secondary scattering effects introduced by the successive depths or layers of partcles. To overcome this difficulty as far as possible, a minimum volume of suspension has been used in the following work. A small volume may be examined experimentally by use of a capillary tube of large external diameter and fine bore.

APPARATUS.

A photograph of the apparatus used is shown in Figure 3, and a diagram in Fig. 4. The light source, L_1, was a 400 watt Pointolite tungsten filament arc lamp operating on a 110 volt direct current circuit. This gave a light of high, uniform intensity without which the work would have been impossible. Lenses F_1 and F_2 serve to focus an image of the lamp target

on the capillary tube C. The cell C is a glass capillary tube selected for freedom from bubbles and imperfections, with

FIG. 3.



Light scattering apparatus.

outside diameter 10 mm., inside diameter 1 mm. A photograph of the cell is shown in Figure 5. Stray light, which

FIG. 4.

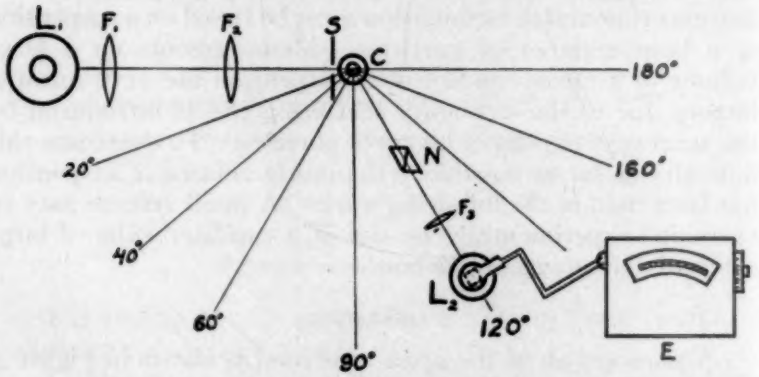


Diagram of the light scattering apparatus.

causes objectionable reflections, is excluded by means of the aperture S. The light scattered by the suspension in the cell is measured at various angles by means of a photometer

mounted on a movable, rotating carriage. This photometer includes a nicol prism, N, a lens F_3 to focus an image of the cell in the eyepiece, a total reflection prism, to reflect the light vertically upward, and an optical pyrometer eyepiece L_2 with

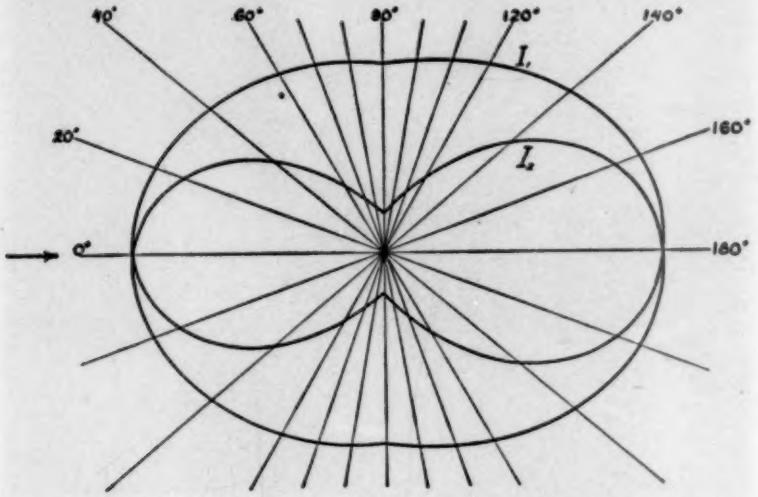
FIG. 5.

Photograph of the capillary tube cell.

variable resistance and milliammeter E. This photometer is calibrated by means of a rotating sector and using a magnesium carbonate block at C. The filament of the lamp L_2 is superimposed on the center of the image of the cell and, therefore, the light scattered from the center of the cell only is measured. In spite of the care used in designing the optical system to measure light from the center of the cell only, the cleanliness of the cell was found to be an important factor. The inside wall was cleaned throughly by scrubbing with concentrated nitric acid, then distilled water, then concentrated sodium hydroxide solution, and again with distilled water. This surface, once cleaned, would remain clean if the cell was kept filled with distilled water. To prevent scattering of light from the minute scratches, as well as dirt, on the outer wall of the cell, a thin

layer of cedar oil was brushed on. This successfully prevented any scattering whatever from the outer wall. To prevent the light directly reflected from the cell walls from entering the photometer eyepiece, it was necessary to place the light beam at a slight angle to the horizontal, as is shown in Fig. 3. This introduces a slight error in the angle at which the scattering

FIG. 6.



Distribution of light scattered by gold sol. (Diameter less than .10 micron.)

is measured. This has not been corrected for, the distribution being given for angles in a plane perpendicular to the cell. The effect of this angle is too slightly fore-shorten the distribution diagrams.

To determine the degree to which the apparatus approached the ideal, use was made of a fine gold suspension. While no direct measurement of the particle size of this material was made, its appearance (very faint turbidity with clear red color) indicates that it is well below .10 micron, and should have a symmetrical distribution of the scattered light. The results obtained on this sol are plotted in Fig. 6. The distribution is very nearly symmetrical; the asymmetry appears to be due to the effect of illuminating the cell at a slight angle, instead of perpendicularly, since illuminating at a greater angle results in a more asymmetrical distribution. The approach to

symmetrical distribution is considered sufficiently close to justify the use of the apparatus in a further study of the angular distribution of scattered light.

In plotting the results given in Fig. 6, the two intensity components of the light, I_1 and I_2, are the two components vibrating at right angles to one another, obtained by placing the nicol prism N in the two positions ninety degrees apart.

A slight correction may be made for the scattering present in pure distilled water. This correction is so small that it has been neglected in all cases except that of the gold sol given above, when the intensities were so low as to make this factor of some importance.

RESULTS OBTAINED.

The results obtained on the seven samples of zinc oxide, determined at a concentration of 1.39×10^{-4} grams per cc., with water as the suspending medium, are tabulated in Table No. 3. A red color screen ($\lambda = 6300$ Å.) was used in the eye-

TABLE No. 3.

No. 1. $d_1 = .135$. Wave-length = 6300 Å.

Angle.	I_1.	I_2.	Angle.	I_1.	I_2.
20.....	.54	.54	100	.710	.15
40.....	.375	.25	110	.810	.25
60.....	.405	.132	120	1.11	.51
70.....	.445	.080	140	2.20	1.33
80.....	.510	.088	160	5.35	4.9
90.....	.580	.088	180	9.2	9.2

No. 2. $d_1 = .192$. Wave-length = 6300Å.

Angle.	I_1.	I_2.	Angle.	I_1.	I_2.
20.....	.71	.73	100	.81	.15
40.....	.54	.35	110	.97	.27
60.....	.48	.18	120	1.42	.62
70.....	.51	.12	140	2.62	1.82
80.....	.58	.088	160	6.05	5.35
90.....	.66	.096	180	12.5	9.2

No. 3. $d_1 = .217$. Wave-length = 6300 Å.

Angle.	I_1.	I_2.	Angle.	I_1.	I_2.
20.....	1.11	1.11	100	.87	.231
40.....	.71	.48	110	1.11	.35
60.....	.54	.27	120	1.51	.66
70.....	.58	.212	140	3.42	2.62
80.....	.62	.162	160	8.6	8.3
90.....	.66	.162	180	14.0	14.5

No. 4. $d_1 = .282$. Wave-length = 6300 Å.

Angle.	I_1.	I_2.	Angle.	I_1.	I_2.
20.....	1.61	1.64	100	.97	.51
40.....	.81	.66	110	1.11	.71
60.....	.66	.445	120	1.72	1.10
70.....	.54	.375	140	3.25	2.62
80.....	.58	.375	160	13.0	9.2
90.....	.66	.405	180	24.0	24.0

No. 5. $d_1 = .404$. Wave-length = 6300 Å.

Angle.	I_1.	I_2.	Angle.	I_1.	I_2.
20.....	1.10	.81	100	.66	.51
40.....	.445	.405	110	.76	.62
60.....	.445	.375	120	.97	.97
70.....	.48	.325	140	2.2	2.2
80.....	.48	.375	160	6.6	7.4
90.....	.51	.405	180	14.5	13.5

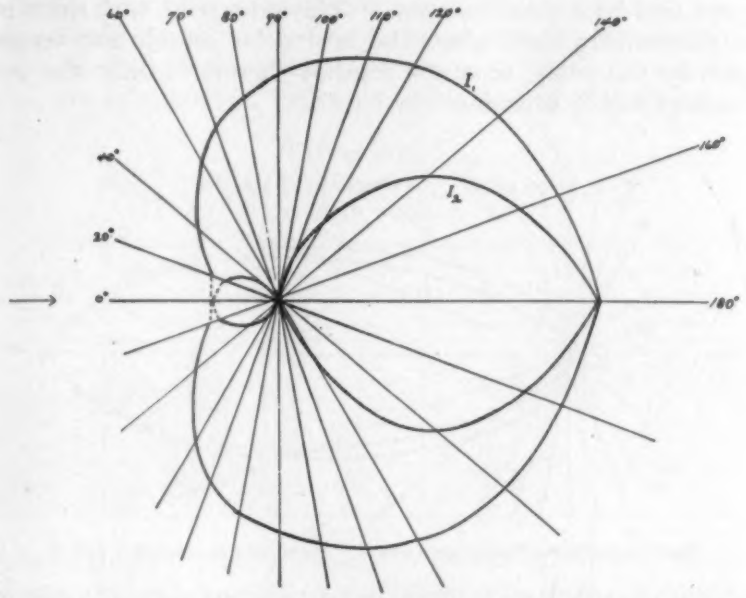
No. 6. $d_1 = .676$. Wave-length = 6300 Å.

Angle.	I_1.	I_2.	Angle.	I_1.	I_2.
20.....	.81	.87	100	.35	.35
40.....	.325	.325	110	.445	.445
60.....	.30	.30	120	.58	.58
70.....	.30	.25	140	.97	.97
80.....	.30	.27	160	2.95	2.5
90.....	.325	.30	180	8.9	9.2

No. 7. $d_1 = 1.23$. Wave-length = 6300 Å.

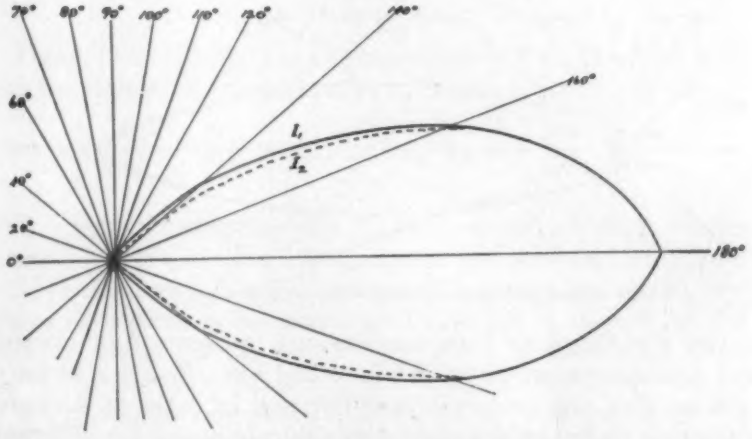
Angle.	I_1.	I_2.	Angle.	I_1.	I_2.
20.....	.48	.51	100	.27	.325
40.....	.325	.27	110	.375	.375
60.....	.25	.23	120	.48	.45
70.....	.25	.25	140	.81	.81
80.....	.212	.23	160	2.08	2.08
90.....	.27	.27	180	6.6	6.3

FIG. 7.



Distribution from a single particle as determined by extrapolation of calculations by Blumer.
d_1 = .135 micron wave-length = 6290 Å.

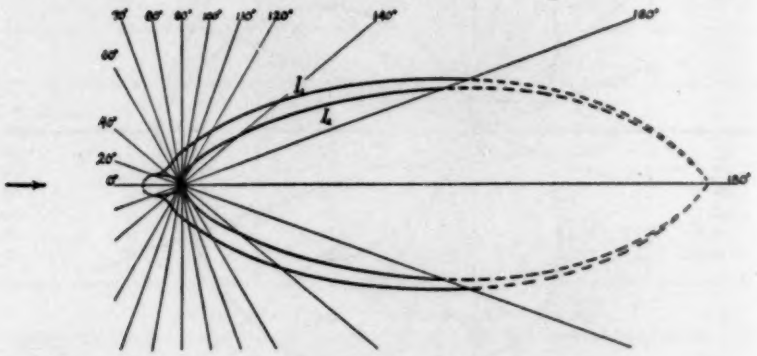
FIG. 8.



Distribution from a single particle as determined by extrapolation of calculations by Blumer.
d_1 = .676 micron wave-length = 6290 Å.

piece. Similar results have also been obtained using the green and blue color screens. The red screen, with the type of photometer used, gives the best color match and consequently the most accurate results; therefore, only the red readings will be considered in detail.

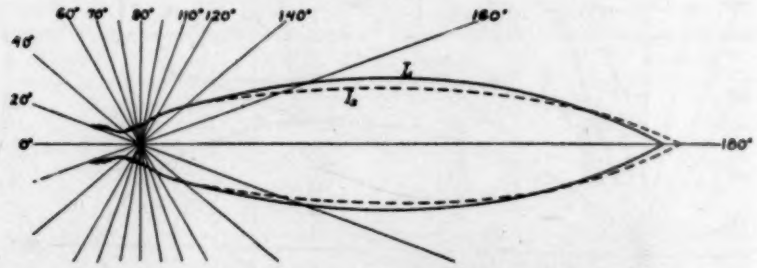
FIG. 9.



Observed distribution from a suspension d_1 = .135 microns wave-length = 6300 Å.

The distributions from single particles, at sizes .135 micron and .676 micron, as extrapolated from the calculations of Blumer are given in Fig. 7 and Fig. 8. Corresponding ob-

FIG. 10



Observed distribution from a suspension d_1 = .676 wave-length = 6300 Å.

served distributions from suspensions, at sizes .135 micron and .676 micron are given in Fig. 9 and Fig. 10. It is at once evident that the tremendous difference in ratio of forward scattering to backward scattering, as calculated for different particle sizes, is not actually observed.

From the calculated figures the ratio of the forward scattered light to that scattered backward, or at ninety degrees, changes rapidly over the range of particles here considered. Several of these ratios, together with the observed ratios, are tabulated in Table No. 4. The observed ratios do

TABLE NO. 4.

Relative Total Intensities $I_1 + I_2$.
Wave-length = 6300 Å.

Particle Diameter d_1.	Ratio of Total Intensity 160°/90°.		Ratio of Total Intensity 160°/20°.	
	Calculated.	Observed.	Calculated.	Observed.
.135	2.39	15.3	4.26	9.5
.192	2.90	15.1	2.72	7.8
.217	3.07	20.5	2.58	7.6
.282	5.10	20.8	8.2	6.25
.404	13.4	15.3	30.7	7.3
.676	37.6	8.7	34.4	3.24
1.23	48.0	7.7	29.3	4.2

not have the large changes indicated in the calculated results and are reversed in order of magnitude. A careful study of the effect of mixtures of zinc oxide of various sizes and of the effect of concentration, failed to indicate any error great enough to explain the lack of agreement.

DEPOLARIZATION.

Gans [13] has pointed out the significance of a figure which he calls the degree of depolarization. It is defined as:

$$\theta = \frac{I_2}{I_1 - I_2}.$$

B. Lange [14] has applied the depolarization to measurements on various sols and shown a fair agreement with the calculated data of Blumer. The depolarization calculated from the figures of Blumer is tabulated in Table No. 5, as well as the observed value for the ninety degree angle, calculated from the values given in Table No. 3. While the observed values do not check the calculated figures exactly, it is seen that the

[13] *Am. Physik.*, **37**, 881 (1912); **62**, 33 (1920).
[14] *Zeit. Phys. Chem.*, **132**, 1 (1928).

general trend and the order of magnitude are the same. The calculated results range from zero through infinity to negative values while the observed results range from .179 to infinity.

TABLE NO. 5.
Depolarization.
Angle — 90 .

Particle Diameter d_1.	Calculated (Blumer) λ = 6290 Å.			Observed λ = 6300 Conc. = 1.38 × 10^{-4} gr./cc.		
	I_1.	I_2.	θ	I_1.	I_2.	θ.
.135	.0075	.0000	.000	.58	.088	.179
.192	.062	.0001	.001	.66	.096	.170
.217	.125	.0008	.006	.66	.162	.27
.282	.340	.015	.046	.66	.405	2.61
.404	.600	.610	−61.	.51	.405	3.86
.676	1.30	3.10	−1.72	.325	.30	12.00
1.23	2.40	3.00	−5.0	.27	.27	

Lange has pointed out the fact that to obtain θ, only the ratio I_2/I_1 is needed. If φ is the angle which the resultant of the two amplitudes makes with the one component,

$$\frac{I_2}{I_1} - = \tan^2 \varphi$$

and

$$\theta = \frac{\tan^2 \varphi}{1 - \tan^2 \varphi}.$$

The determination of φ requires a much simpler procedure than the determination of I_1 and I_2, and the instrument was modified for this purpose. The nicol prism and photometer eyepiece were removed and replaced by an optical system consisting of a slit, a fixed Wollaston prism, and a rotatable nicol prism. The Wollaston prism forms two images of the cell, corresponding to the two directions of vibration of the light. The angle φ is obtained by rotating the nicol until the two images appear equal in intensity.

One series of observed values of φ obtained on the modified apparatus and the corresponding values of θ are recorded in Table No. 6. A negative value for θ indicates an angle greater than 45°, or I_2 greater than I_1.

TABLE NO. 6.

Depolarization (Observed).

Angle = 90°. Wave-length = 6300 Å. Concentration = 2.78×10^{-5} grams per cc.

No.	Particle Diameter d_1.	φ.	$\tan^2$.	θ.
1	.135	20.2	.135	.16
2	.192	19.2	.121	.14
3	.217	23.5	.19	.24
4	.282	35.6	.51	1.04
5	.404	39.2	.662	1.96
6	.676	41.1	.76	3.16
7	1.23	42.4	.833	5.00

Gans has pointed out that θ varies with the concentration and derives the relation:

$$\frac{\theta - \theta_0}{1 + \frac{5}{3}\theta} = 2\,a\,C,$$

where θ_0 is the depolarization at zero concentration, therefore, for a single particle,

C is a constant proportional to the concentration,
a is a constant dependent on the shape of the particles.

Lange extends this so that if the values of θ_1 and θ_2 at two concentrations c_1 and c_2 are determined, θ_0 may be calculated as:

$$\theta_0 = \frac{\frac{c_1}{c_2}\theta_2\,(1 + \frac{5}{3}\theta_1) - \theta_1\,(1 + \frac{5}{3}\theta_2)}{\frac{c_1}{c_2}(1 + \frac{5}{3}\theta_1) - (1 + \frac{5}{3}\theta_2)}.$$

Using this relation, the value of θ_0 has been calculated from the observed values of θ at two concentrations and the results are recorded in Table No. 7. The values should correspond to those calculated from Blumer's data and the agreement is shown by the plot in Fig. 9. θ_0 does not have zero value at small particle sizes and it begins to increase rapidly for somewhat smaller sizes than in the case of Blumer's figures. The general shape of the curve, however, is the same.

Differences may be partly attributed to error in particle size determination, to the non-uniformity of particle size, and to the shape of the particles. Blumer's figures are based on spherical particles, while the zinc oxide particles are at best only approximately spherical in shape.

TABLE NO. 7.

Depolarization θ_0

Calculated from Observed θ

Angle = 90° Wave-length = 6300 Å.

Particle Diameter d_1.	θ_1 at Concentration 2.78×10^{-5} gr. per cc.	θ_2 at Concentration 1.39×10^{-4} gr. per cc.	θ_0.	θ Calculated (Blumer).
.135	.16	.18	.09	.00
.192	.14	.22	.12	.001
.217	.24	.29	.23	.006
.282	1.04	1.18	1.01	.046
.404	1.96	5.30	1.65	−61.0
.676	3.16	7.85	2.70	−1.72
1.23	5.00	−4.57	2.90	−5.0

The values of θ obtained with mixtures of two of the pigments indicate that this factor may be of value in determining the amount of fine and coarse material in a specimen of zinc oxide. At the concentration 1.39×10^{-4} grams per cc. the value of θ for No. 1 is .174 and for No. 6 is 7.85. Ten per cent. by weight of No. 6 added to No. 1 gives $\theta = 1.02$ and fifty per cent. gives $\theta = 6.7$. This indicates that the failure of samples 1 and 2 to approach a zero value for θ may be due to their having two to three per cent. of large particles or aggregates.

SUMMARY.

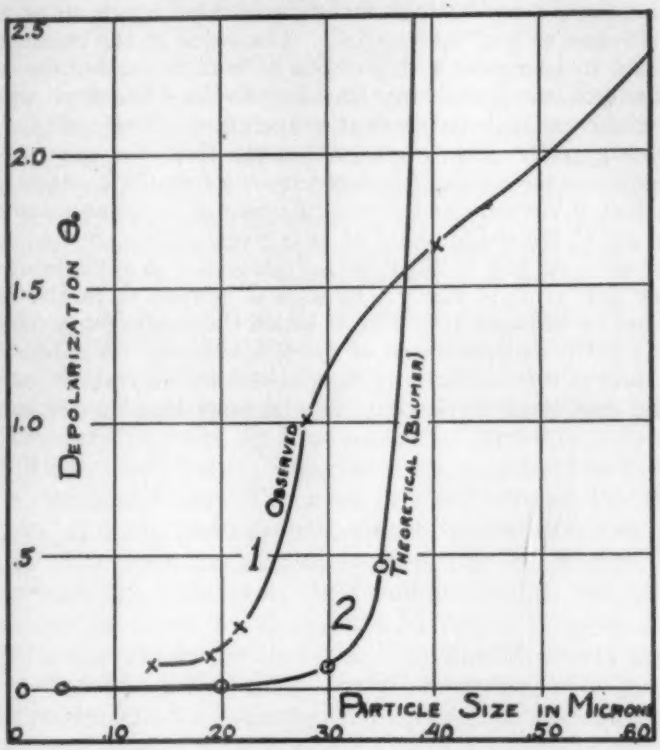
1. The turbidity maximum for zinc oxide dispersed in water is determined for three wave-lengths of light. The maximum occurs at .25 micron for wave-length 5500 Å.

2. The turbidity maximum occurs at smaller particle sizes for shorter wave-lengths. The particle size of maximum turbidity is found to be proportional to the wave-length of the light in the range of wave-lengths from 4800 Å. to 6300 Å.

3. An apparatus is described for determining the angular distribution of the light scattered by a suspension of fine particles.

4. The total intensity of the scattered light as observed does not have the same distribution as the calculated values of Blumer.

FIG. 11.



Depolarization δ calculated from results of Blumer, and from observed figures.

5. The depolarization, $\frac{I_2}{I_1 - I_2}$, as observed, follows the general trend of the theoretical values.

The author is indebted to Dr. A. H. Pfund for his help and many timely suggestions, particularly that of using a capillary as the cell; to Professor K. F. Herzfeld for his interest and help with the theoretical considerations; and to Mr. G. S. Haslam for his great assistance in setting up the apparatus and making the observations.

The Thermal Conductivity up to 500° C. of Nitrogen Derived from the Air. T. WILNER AND G. BORELIUS. (*Annalen der Physik*, Vol. 4, No. 3, 1930.) The authors made an investigation of the heat conductivity of thermal insulators in the form of powders and have now extended their measurements to include air at 24° C. and nitrogen at 325° and 500° C. The value of the conductivity of air was in agreement with previous determinations but the results for nitrogen are noteworthy because they are the first accurate determinations made for gases at temperatures above 200° C. The previously given values of thermal conductivity for gases at high temperatures have been calculated from a formula containing the coefficient of viscosity and the specific heat at constant volume.

At 24° C. the conductivity of air is given as 60×10^{-6} g.cal./cm. degree sec. At 325° C. the value for nitrogen is 96 in the same units and at 500° C. it is 112. A formula is derived to fit the results obtained for nitrogen according to which the conductivity increases linearly with the square root of the temperature. It appears that the values of the conductivity computed from the formula containing the coefficient of viscosity may be more than 10 per cent. in error.

G. F. S.

MEDAL DAY MEETING.

MAY 21, 1930.

The annual Medal Day Meeting of The Franklin Institute was held in the Hall of the Institute at three-thirty o'clock on the afternoon of Wednesday, May 21, 1930. It was also the stated monthly meeting of the Institute and was called to order by Mr. Nathan Hayward, President.

The Chairman announced that the minutes of the April meeting of the Institute were published in full in the May number of the JOURNAL of the Institute and that, if no objections were offered they would be approved as printed. No objection was offered and the minutes were declared by the President to be approved. The Chairman then called upon the Secretary to make an announcement concerning the various gifts and bequests. The Secretary reported the bequest of Dr. William Henry Trueman of Philadelphia, Penna., of $28,300, and his photographic books, periodicals and pamphlets. The Secretary also announced that Mr. Samuel Insull of Chicago, the founder of the Franklin Medal, had made a handsome addition to that fund in order to give to the Institute the ability to have the Franklin Medalists present at the Medal Day Exercises. Brief references to the progress of the movement for the establishment on the Parkway of the Benjamin Franklin Memorial and Franklin Institute Museum, were also made by the Secretary.

The Chairman then announced that the presentation of Certificates of Honorary Membership and Certificates of Merit would be the next order of business and stated that all Medals and Certificates, the awards of which had been recommended during the present Institute year by the Committee on Sciences and the Arts, would be presented at this time.

HONORARY MEMBERSHIP.

To Dean Emeritus, Mortimer Elwyn Cooley, of the University of Michigan. The Secretary of the Institute, Dr. McClenahan, sponsor.

The Chair recognized the Secretary.

Dr. McClenahan: "Mr. President, I have the honor to present to you, *in absentia*, Dean Emeritus, Mortimer Elwyn Cooley, LL.D., Eng.D., Sc.D., of the University of Michigan, as a candidate for Honorary Membership in The Franklin Institute 'in recognition of his inspiring guidance in engineering education and of friendly reasonableness, enlightened judgment, and fearless integrity, in the practice of his profession.' I deeply regret, as does Dean Cooley, that he is unable, because of illness, to be with us today. If you will entrust me with this Certificate of Honorary Membership, I will promise faithfully to forward it to its proper recipient."

The Chairman presented the Certificate of Honorary Membership as follows:

"I have much satisfaction in conferring honorary membership upon Doctor Cooley and wish that you (Dr. McClenahan) transmit this certificate to him with my very best wishes."

To Dr. Henry Leffmann of Philadelphia, Penna. The Secretary of the Institute, sponsor.

The Chairman: "Has the Secretary any further recommendation?"

Dr. McClenahan: "Mr. President, I have a peculiar pleasure in presenting to you, as a candidate for Honorary Membership in The Franklin Institute, Dr. Henry Leffmann, 'in recognition of valuable services to science in research, in teaching, as former Port Physician of the City of Philadelphia, and as a discriminating but good-tempered critic.' Mr. President, I present Dr. Leffmann."

The President presented the Certificate as follows:

"Doctor Leffmann, it is with a great deal of appreciation of your services to the Institute that I present to you this Certificate of Honorary Membership in this ancient society. I thank you for all you have done and may I add a personal statement of my pleasure in so honoring you."

Doctor Leffmann: "Mr. President, members of the Board of Managers, members of the Institute and guests, I wish to express my appreciation of the honor conferred upon me. The long service of The Franklin Institute in the promotion of applied science and the mechanic arts makes honorary membership therein indeed a great honor.

AWARD OF THE CERTIFICATE OF MERIT.

To Mr. Heyman Rosenberg, of New York. Mr. Henry B. Allen, sponsor.

The Chair recognized Mr. Allen.

Mr. Allen: "Mr. President, upon the recommendation of the Committee on Science and the Arts, I present to you, Mr. Heyman Rosenberg of the Parker-Kalon Corporation, as the recipient of a Certificate of Merit, 'in consideration of the successful modification of screws, consisting of hardening the threads, thus permitting them to thread their own way when driven or turned into the material to be joined, and the invention whereby the diameter of the body at the base of the thread is less than that of the cylindrical end."

The President presented the Certificate of Merit, as follows:

"In accordance with this recommendation and by my authority as President of The Franklin Institute, I present to you this Certificate of Merit."

AWARD OF EDWARD LONGSTRETH MEDALS.

To Mr. Ervin George Bailey, of Fullerton, Pennsylvania. Mr. Coleman Sellers, 3d, sponsor.

The Chair recognized Mr. Sellers.

Mr. Sellers: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts, Mr. Ervin George Bailey, President of the Fuller Lehigh Company and of the Bailey Meter Company, as the recipient of the Edward Longstreth Medal, 'in consideration of his invention and development of regulating and controlling and of measuring and recording instruments.'"

The President presented the Medal and Certificate, as follows:

"In the name of The Franklin Institute and upon the recommendation which the Committee on Science and the Arts presented in the report just read, I, as President of the Institute, present to you the Edward Longstreth Medal."

To Professor Charles Weyl, Assistant Professor Electrical Engineering, University of Pennsylvania. Professor H. Jermain Creighton, sponsor.

The Chair recognized Dr. Creighton.

Dr. Creighton: "Mr. President, it gives me much pleasure to present to you, upon recommendation of the Committee on Science and the Arts, Professor Charles Weyl, Assistant Professor of Electrical Engineering in the University of Pennsylvania, as the recipient of the Edward Longstreth Medal, 'in consideration of the ingenious adaptation of mechanical and electrical principles to the operation of an x-ray apparatus which has proved useful in the diagnosis of certain diseases in their early stages of development.'"

The President presented the Medal and Certificate, as follows:

"Upon the recommendation of the Committee on Science and the Arts as just given, I present to you in the name of The Franklin Institute the Edward Longstreth Medal."

Professor Weyl: "Mr. President, I appreciate the honor and I thank you for it."

AWARD OF WETHERILL MEDALS.

To Charles Sumner Chrisman, West Chester, Pennsylvania. Mr. Harold Calvert, sponsor.

The Chair recognized Mr. Calvert.

Mr. Calvert: "Mr. President, in accordance with the findings of our Committee on Science and the Arts, it is my privilege to present to you, Mr. Charles Sumner Chrisman, to receive the John Price Wetherill Medal, because of 'his ingenious and economical improvements, in the apparatus for, and methods of, gas manufacture.'"

The President presented the Medal and Certificate, as follows:

"In the name of The Franklin Institute upon the recommendation which the Committee on Science and the Arts has presented in the report just read, I give you the John Price Wetherill Medal."

Mr. Chrisman: "Mr. President, I wish to thank you for the award, it is highly appreciated."

To William Nicholson Jennings, Philadelphia, Pennsylvania. Mr. Lionel F. Levy, sponsor.

The Chairman: "We shall be pleased to hear from Mr. Levy."

Mr. Levy: "Mr. President, the Committee on Science and the Arts, recommends unanimously the award of a John Price Wetherill Medal to Mr. William N. Jennings, 'in consideration of his pioneer work in the photography of flashes of lightning.' Mr. Jennings' work in this field antedated the work of all other men and was carried out with but few of the experimental aids of modern high-speed photography."

The President presented the Medal and Certificate as follows:

"Upon the recommendation of the Committee on Science and the Arts, as just given, I, as President of The Franklin Institute, have the honor to present to you the John Price Wetherill Medal. It is peculiarly gratifying to us to be able to present a Medal to one of the Members of our own Committee on Science and the Arts, for such important and original work."

Mr. Jennings: "I greatly appreciate the honor conferred upon me and I would like at this time to acknowledge my indebtedness to Doctor Kimball and Doctor Goodspeed who helped me carry out my first experiments. In those days we had only slow lenses and it took a long time before we were able to make satisfactory pictures of lightning. That was a long long time ago."

AWARD OF LEVY MEDAL.

To Dr. Floyd Karker Richtmyer, Ithaca, New York. Dr. Frederick Palmer, Jr., sponsor.

The Chairman: "May I call upon Professor Palmer of Haverford College?"

Dean Palmer: "Mr. President, upon the unanimous recommendation of the Committee on Science and the Arts, I have the honor to present to you, Dr. Floyd Karker Richtmyer, Professor of Physics in Cornell University, as the recipient of the Louis E. Levy Medal for his paper in the September 1929 issue of THE JOURNAL OF THE FRANKLIN INSTITUTE, entitled, 'Some Secondary Phenomena in X-ray Spectra.' This paper contains new matter of importance concerning X-rays, leading to further understanding of atomic structure."

The President presented the Medal and Certificate as follows:

"In the name of The Franklin Institute and upon the recommendation of the Committee on Science and the Arts, whose report has just been read, I, as President of The Institute have the honor to give you the Louis Edward Levy Medal."

Dr. Richtmyer: "Mr. President, I wish to express to you, to the Institute and to your colleagues my sincere thanks and appreciation for this honor."

AWARD OF HENDERSON MEDALS.

To Mr. George Hannauer (posthumous award), Chestnut Hill, Massachusetts, and Mr. Edgar Marvin Wilcox, of Gibson, Indiana. Mr. Walter C. Wagner, sponsor.

The Chairman: "Will you, Mr. Wagner, address the Chair?"

Mr. Wagner: "Mr. President, it gives me much pleasure to present to you, as President of The Franklin Institute, upon the recommendation of the Committee on Science and the Arts, Mr. George Hannauer, Jr., as the representative of the late George Hannauer, and Mr. Edgar Marvin Wilcox, of the Hannauer Car Retarder Company, as the recipients of the George R. Henderson Medals, 'in consideration of the develop- of the Car Retarder System and the contributions of the inventors to railway engineering.'"

The President presented the Medals and Certificates, as follows:

"The Franklin Institute, upon the recommendation of its Committee on Science and the Arts which you have just heard, in recognition of the joint work of Mr. George Hannauer and Mr. Edgar M. Wilcox, awards the George R. Henderson Medal, which it is my honor to present to you, Mr. Wilcox, and to you, Mr. Hannauer, to hold in memory of your father's great work."

Mr. Wilcox: "I am very appreciative of the interest manifested in myself as well as in the work of the late Mr. Hannauer."

AWARD OF WALTON CLARK MEDAL.

To Henry Latham Doherty, of New York City. Mr. John M. Rusby, sponsor.

The Chair recognized Mr. Rusby.

Mr. Rusby: "Mr. President, I have unusual pleasure in presenting to you, upon the unanimous recommendation of the Committee on Science and the Arts, Mr. Henry Latham Doherty, President of Cities Service Corporation, as the recipient of the Walton Clark Medal, 'in consideration of his outstanding and valuable work in the development of the manufactured gas industry.' Mr. Doherty's contributions to the gas industry have been revolutionary and epoch-making in character."

The President presented the Medal and Certificate, as follows:

"As President of The Franklin Institute, on recommendation of the Committee on Science and the Arts, whose report has just been read, in recognition of this remarkable work which you have done and which all of us have watched with keen interest for so many years, I have the honor to present to you the Walton Clark Medal which was founded to honor Dr. Walton Clark, a man whom you and all of us so greatly admire."

Mr. Doherty: "Mr. President, I thank you."

AWARD OF ELLIOTT CRESSON MEDALS.

To Mr. Norman Rothwell Gibson, Niagara Falls, New York. Mr. Frank H. Rogers, sponsor.

The Chairman: "Mr. Rogers you have the floor."

Mr. Rogers: "Mr. President, upon the recommendation of the Committee on Science and the Arts, I present to you with high appreciation of the value of his researches, Mr. Norman Rothwell Gibson, to receive an Elliott Cresson Medal, 'in consideration of his originality in first adapting a well-known law of mechanics to the measurement of flowing water, his skill and ingenuity in developing apparatus for accurately recording the required data, the simplicity, accuracy and economy of his method, the wide scope of its application in measuring the flow of liquids and its very general adaptation in commercial work."

The President presented the Medal and Certificate as follows:

"In the name of The Franklin Institute on recommendation of the Committee on Science and the Arts and in recognition of this most important work which you have done, by authority vested in me as President of the Institute, I award you the Elliott Cresson Medal which was founded by a member of The Franklin Institute in 1848."

Mr. Gibson: "Mr. President, I wish to express to you my deep appreciation of this high honor."

To Mr. Irving Edwin Moultrop, Boston, Mass. Mr. M. M. Price, sponsor.

The Chair recognized Mr. Price.

Mr. Price: "Mr. President, I deem it an honor to present to you, as President, upon recommendation of the Committee on Science and the Arts, Mr. Irving Edwin Moultrop, Designer and Chief Engineer of the Boston Edison Company, as the recipient of an Elliott Cresson Medal, 'in consideration of the engineering skill displayed in the design and construction of the high pressure installation at the Edgar Station, whereby a marked advance in the art of steam electric generation was accomplished and a reliable source of information for advance prediction, not only of performance but of initial cost of such stations was made available, and in which courage of high order was manifested.'"

The President presented the Medal and Certificate as follows:

"In recognition of this work which is of such fundamental importance to the welfare of every user of electricity, by the authority vested in me as President of The Franklin Institute, I award to you the Elliott Cresson Medal."

Mr. Moultrop: "Mr. President, I am deeply grateful to you and The Franklin Institute for the honor conferred upon me. There is only one thing I regret in receiving this award—that is that one of my lifelong friends, Dr. Wm. C. L. Eglin, could not be present to see me get this medal."

Mr. Hayward: "May I thank you for mentioning a man whom the Institute honors?"

AWARD OF FRANKLIN MEDALS.

To Dr. John Frank Stevens, Baltimore, Md. Dr. James Barnes, sponsor.

The Chairman: "The Chair calls upon Dr. Barnes to present the Franklin Medalist of the day."

Dr. Barnes: "Mr. President: The Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and Art is unanimously of the opinion that a Franklin Medal be awarded to Dr. John Frank Stevens, 'In recognition of his unifying solutions of widely varying and difficult engineering problems met in the planning of the great Panama Canal, of the marked power shown by him in the organization of the engineering forces which later built that canal, and of his eminent success in the location, construction and administration of railroads in this country and in foreign lands.'

"Doctor Stevens was born at West Gardiner, Maine, in 1853. His first engineering experience was with a firm of engineers at Lewiston, but he was soon drawn to the West. From 1874, to almost the present time he has been associated with many American railroads, among them may be mentioned the Denver and Rio Grande, the Chicago, Milwaukee and St. Paul, the Canadian Pacific, the Great Northern, and the New York, New Haven and Hartford. His list of honors from Governments is a long one, including the Distinguished Service Medal of the United States. He is an officer of the Legion of Honor of France. In 1925 he was awarded the John Fritz Medal, the highest honor American engineers can pay to one of their number.

"I should like to bring to your attention a few of his splendid achievements.

"In 1889 the Great Northern Railway extended to Butte, Montana. Its President, Mr. Hill, had his eyes on the Orient and his heart was set on pushing his rails over the Rockies to the Pacific. Early in that year Mr. Stevens entered the service of this railroad and was assigned the task of locating the line over the mountains.

"The country west of Havre, Montana, was at that time occupied by Blackfeet Indians and in his associations with them he learned that one of their legends mentioned a pass

through the Rockies at the head of the Marias River. The Indians, however, warned him that in that pass dwelt an evil spirit. Their advice was to keep away from it for they assured him he would never return alive. This warning did not deter him. In December of that year Stevens, accompanied by a half-breed Indian, found the pass. At this time of the year it was, of course, bitterly cold, around 40° below zero, the snow was knee deep; the men with packs on their backs were using snowshoes and the half-breed became exhausted and refused to proceed. Stevens went on alone and on the night of the 11th satisfied himself that he had crossed the divide and was in the Pacific drainage. He himself has said this: 'It was a most interesting night for tramping there in the darkness to keep from freezing. I saw as clearly as if it were already a reality exactly how the trains of the Great Northern would go sweeping through those mountain fastnesses in the months to come.'

"The thoroughness with which Stevens covered the country enabled him to say it was the lowest and best pass across the Rockies in the Northern United States.

"Four years later the first transcontinental express rushed through this pass by the straightest route from the head waters of the Mississippi to Portland and Puget Sound.

"In grateful recognition of this service the Great Northern Railway has caused an heroic bronze statue of Dr. Stevens to be erected on the summit of that pass where he spent that memorable night.

"In 1905, Dr. Stevens was called by our Government to take charge of the work of constructing the Panama Canal. When he arrived at the Canal Zone everything was in a chaotic state. Quiet and unassuming but sure and unhesitating he went about his job, the unprecedented magnitude of which can best be judged when one considers that many millions of cubic yards of rock and earth had to be removed to form that canyon, the famous Culebra Cut, and also that almost as much material was required to rear the Gatun Dam. At Gatun also the duplicate flight of three locks required the greatest mass of masonry ever laid together since the days of the Egyptians, for these locks measure in volume half that of the Great Pyramid. The Panama Canal is without a doubt

one of the greatest wonders of the modern world, truly a 'living memorial' to the engineering genius of Dr. Stevens.

"After he had spent eighteen months as Chief Engineer of the Panama Canal, bringing order out of chaos, planning all the details of construction and of organization, starting the vast machine going with a contented and healthy army of 30,000 men, he resigned and the work was completed by others.

"In 1917, in consequence of the collapse of the Russian Imperial Government the operation of the Trans-Siberian and the Chinese Eastern Railways was practically brought to a standstill. This great trade route was, during the time of the World War, of great economic and military value to the Allies. Lengthy negotiations eventuated in what is now known as the Inter-Allied Agreement of 1919 for the control and supervision of these railways. Under the agreement two Boards were created, one a military transportation board and the other a technical board. Dr. Stevens was made President of this latter Board and to him has been given the credit of saving these railroads from certain destruction and of operating them under the most difficult and trying circumstances all the way from Vladivostok to Moscow. Our fellow citizen, the Honorable Roland S. Morris, then Ambassador to Japan said: 'It was an extraordinary service he rendered.'

"Mr. President: Many New Englanders following more or less in the footsteps of Benjamin Franklin have come to Philadelphia and have thrived. Today another man from 'Down East,' should I say another 'man from Maine,' has come to town. His reputation and his fortune have, however, been made. He honors us with his presence and we wish to honor him with our highest award, the Franklin Medal, and Certificate of Honorary Membership in The Franklin Institute. I, therefore, have the honor and pleasure of presenting to you, sir, this very distinguished engineer and public benefactor, Dr. John Frank Stevens."

The President presented the Medal and Certificate and Certificate of Honorary Membership, as follows:

"Dr. Stevens, in recognition of these far-reaching works in engineering which have just been so well described, The Franklin Institute awards you the Franklin Medal which is

the highest award in its gift. By the authority invested in me as President of this Institute I present to you this medal and the Certificate of Honorary Membership."

Dr. Stevens: "Mr. President, through you I want to thank the Institute for this great honor."

To Sir William Henry Bragg, F.R.S., LL.D., D.Sc. Dr. James Barnes, sponsor.

The Chairman: "Dr. Barnes."

Dr. Barnes: "Mr. President: The Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and the Arts is unanimously of the opinion that a Franklin Medal be awarded to Sir William Henry Bragg, 'in recognition of a life-work in the study of x-rays and radioactivity in the course of which he made fundamental contributions to that realm of physics, of his development of a method of determining molecular and crystal structure by the reflection of x-rays and of his fruitful guidance of the Davy-Faraday Research Laboratory and of the Royal Institution of Great Britain.'

"Sir William was born at Wigton, England, in 1862. His collegiate education was obtained at Trinity College, Cambridge. In 1886, he was appointed professor of mathematics and physics in the University of Adelaide, Australia, and while there began his investigations in the field of radioactivity. He took an active interest in the development of scientific research in Australia and was a member of the Council of the South Australian School of Mines and Industries. In 1909 he was appointed Cavendish Professor at Leeds University. In 1915 he became Quain Professor of Physics at the University of London where he remained until his election in 1923 to his present position as Director of the Royal Institution of Great Britain, Fullerian Professor of Chemistry at the Royal Institution and Director of the Davy-Faraday Research Laboratory. He is a Fellow and a Rumford medalist of the Royal Society. In 1915 he received the Nobel Prize for physics, which distinction he shared with his son, Professor W. Lawrence Bragg. This is a family achievement of the highest order, without a precedent and with a small mathematical probability coefficient of recurrence in the ages to come.

"During the World War he placed his services at the disposal of the British Admiralty where he was especially associated with the problem of submarine detection. In 1917 his public services were acknowledged by the King in the bestowal of the title, Commander of the Order of the British Empire and by his creation as Knight Commander of the same Order in 1920.

"Sir William's extensive and valuable studies have been in the modern and important fields of radio-activity, x-rays, and crystal structure; in fact they are of such a fundamental nature that his name is a household word to all students in the exact sciences.

"In radioactivity his experiments on the determination of the ranges of the alpha particles from various radioactive substances throw much light on the mechanics of ionization in gases and on the laws of absorption of these rays by matter.

"In the field of x-rays and crystal structure he showed that the cleavage faces of a crystal reflect x-rays according to the same laws that apply in ordinary optical reflection and he derived the formula known as the Bragg equation for space lattices. Using this equation and with observations made on numerous crystals by means of an x-ray spectrometer of his own design he determined the various distances between the atomic planes in these crystals and the nature of the atoms in these planes. In this way he put crystallography on an exact and measurable foundation. It is of interest to note in passing that Moseley, using this method, made his epoch-making contribution to science when he showed that the so-called atomic numbers and not the atomic weights were the most important factors in the study of the physical and chemical properties of atoms.

"The list of Sir William's scientific publications is a long one. His power of lucid exposition of difficult scientific ideas is well known and is illustrated in those most fascinating books entitled 'The World of Sound,' 'Concerning the Nature of Things,' 'Old Trades and New Knowledge.'

"Mr. President, it is our good fortune to have Sir William with us today. To him honors and medals must be commonplace, nevertheless we ask you to bestow upon him our medal which bears the name and medallion of a great American,

together with the Certificate of Honorary Membership in The Franklin Institute. I, therefore, have the honor and pleasure of presenting to you this distinguished scientist, educator and counselor, Sir William Bragg."

The President presented the Medal and Certificate and Certificate of Honorary Membership, as follows:

"In recognition of this work which has had such a far-reaching effect on the scientific development of the modern world, The Franklin Institute awards to you its Franklin Medal, the highest award in its power to give. As President of this Institute, it is my privilege to present this Medal to you and with it a Certificate of Honorary Membership. May I add, Sir William, a word of pleasure which it has given us that you should have been able to cross the Atlantic in order to join our Annual Meeting."

Sir William: "I wish to express appreciation of the kindness in giving me this Franklin Medal but I am sure that you all feel as I, that it is an award from The Franklin Institute in America to the Royal Institution in England.

"I most highly appreciate the kind welcome given me when I come here. Even the foreboding and stern-faced custom officer said, when I told him I was coming over to receive the Franklin Medal, that he supposed that would be a very pleasant job."

The Chairman: "After the excellent account given by Dr. Barnes of the work of Dr. Stevens, it would be like bringing coals to Newcastle to say anything more about Dr. Stevens than to ask him to speak."

Dr. Stevens then read his paper, entitled, "A MOMENTOUS HOUR AT PANAMA." [1]

The Chairman: "I thank you, Dr. Stevens. Ladies and gentlemen, I have much pleasure in presenting to you the second speaker of the day, who has come to us from London to be the recipient of a Franklin Medal and to present a paper telling of his own epoch-making researches. I have great honor in presenting to you the Director of The Franklin Institute's English twin, the Royal Institution of Great Britain. I present Sir William Bragg, who will tell of 'The Meaning of the Crystal.'"

[1] See page 1.

Sir William Bragg then read his paper, entitled "The Meaning of the Crystal." [2]

The Chairman: "I thank you, gentlemen, for a most splendid and interesting afternoon. The meeting is adjourned."

[2] See page 9.

Comparison of Sunspot Numbers, Terrestrial Magnetic Activity and Long Wave Radio Signal Strength. L. W. AUSTIN. (*Jour. Washington Academy of Sciences*, March 4, 1930.) Four curves are given showing from January 1924 to December 1929 the monthly averages of these four quantities, (*a*) sunspot numbers, (*b*) terrestrial magnetic activity as measured by the horizontal range at Cheltenham, Md., (*c*) daytime ratio field strength of signals received in Washington from the Bordeaux station, wave-length of 18,900 meters, and (*d*) the same ratio for signals from Nauen, wave-length 12,800 m. The sunspot curve does not closely resemble the others, but there is much similarity in the other three curves. In all five years, for example, they all have a minimum in or near to November. "This early winter drop in signals has often been noticed, and in the case of transmission between Europe and America, has been sometimes ascribed to the proximity of the signal path to the area of Arctic darkness. It now appears that this and other seasonal variations both in magnetic activity and East-West long wave signal strength may be due to common causes."

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NATIONAL HYDRAULIC LABORATORY.

On May 14 last, the following bill was signed by the President:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That there is hereby authorized to be established in the Bureau of Standards of the Department of Commerce a national hydraulic laboratory for the determination of fundamental data useful in hydraulic research and engineering, including laboratory research relating to the behavior and control of river and harbor waters, the study of hydraulic structures and water flow, and the development and testing of hydraulic instruments and accessories: Provided, That no test, study, or other work on a problem or problems connected with a project the prosecution of which is under the jurisdiction of any department or independent agency of the Government shall be undertaken in the laboratory herein authorized until a written request to do such work is submitted to the Director of the Bureau of Standards by the head of the department or independent agency charged with the execution of such project: And provided further, That any State or political subdivision thereof may obtain a test, study, or other work on a problem connected with a project the prosecution of which is under the jurisdiction of such State or political subdivision thereof.

Sec. 2. There is hereby authorized to be appropriated, out of any money in the Treasury not otherwise appropriated, not to exceed $350,000, to be expended by the Secretary of Commerce for the construction and installation upon the present site of the Bureau of Standards in the District of Columbia of a suitable hydraulic laboratory building and such equipment, utilities, and appurtenances thereto as may be necessary.

* Communicated by the Director.

A number of Government departments have a long list of urgent problems awaiting solution, and the experiments in connection therewith will be taken up in the new laboratory as soon as it is completed. Among these are questions relating to large reclamation and water conservation projects in the West, the control of erosion below spillways and dams, losses of head in large pipe and channel bends, the flow of water over dams, the entrainment of air at tunnel and syphon entrances, the regulation of rivers, the laws of silting and erosion in drainage ditches and streams, and the improvement of instruments and devices for measuring flowing water.

Owing to the great variety of problems which will be submitted for study, the equipment of the new laboratory will be designed to furnish the greatest possible flexibility of arrangement and combination, so that it can be adapted easily to the simultaneous study of a number of different problems.

The fixed equipment will include electrically-driven pumps for circulating the water, a large concrete water supply basin, a concrete measuring tank, several steel weighing tanks, elevated control tanks for supplying water under several different fixed heads, a stand-pipe and piping systems for distributing this water to all parts of the laboratory and for returning it from the models under test to the supply basin. A large unobstructed floor will be provided where a number of models can be built and tested simultaneously.

THERMAL EXPANSIONS OF FUSED ALUMINA, BAUXITE, AND DIASPORE.

Among the refractory materials included in an investigation of the linear thermal expansion of special refractories from atmospheric temperature to 1800° C. are samples of fused alumina (artificial corundum), bauxite containing approximately 80 per cent. alumina (water-free basis), and diaspore of the grade used in the manufacture of refractories.

The data obtained are as follows:

A. Corundum. Specimens commercially prepared.

1. Tested as received.

1*a*. Maximum expansion, 1.13 per cent. obtained at 1480° C.

1*b*. Rate of expansion uniform, increasing very slowly to approximately 1000° C. and decreasing gradually up to 1480° C. Specimen contracted rapidly from 1480° C. to 1800° C.

1*c*. Petrographic examination shows material to be composed almost entirely of corundum.

2. Tested after heating twice to 1800° C.

2*a*. Maximum expansion, 1.49 per cent., obtained 1750° C.

2*b*. Coefficient of expansion from 20° C. to 1750° C. is 8.6×10^{-6}.

2*c*. Rate of expansion fairly uniform up to 1360° C.; from 1360° to 1585° C., it decreases decidedly, and increases from 1585° to 1750° C.

2*d*. Material shows no deformation after completion of tests.

2*e*. Petrographic examination shows corundum crystals to be slightly larger than before heat treatment. A rim of mullite is around some of the crystals.

B. Bauxite.

1. Specimen fired at 1400° C. for 5 hours.

1*a*. Maximum expansion, 0.72 per cent. at 1100° C.

1*b*. Expansion uniform from 20° to 1100° C. with specimen contracting rapidly after passing 1100° C.

1*c*. Petrographic examination shows material to consist principally of corundum, mullite and glass. Probably about 70 per cent. corundum present.

2. Specimen heated to 1675° C.

2*a*. Maximum expansion, 1.38 per cent., obtained at 1300° C.

2*b*. Impurities present caused rapid contraction of the material beginning at 1400° C.

2*c*. Average coefficient of linear thermal expansion from 20° to 1300° C. is 8.1×10^{-6}.

2*d*. Specimen showed decided deformation after heating.

2*e*. Petrographic examination shows less corundum present and the mullite crystals to be much larger than in specimen heated to 1400° C.

C. Diaspore.

1. Heated to approximately 1575° C.

1*a*. Maximum expansion, 0.99 per cent. obtained at 1280° C.

1*b*. Specimen contracted rapidly after reaching 1360° C.

1*c*. Petrographic examination indicates the material to be composed almost entirely of corundum and glass.

2. Specimen heated to 1730° C.

2*a*. Maximum expansion, 1.18 per cent., obtained at 1580° C.

2*b*. Average coefficient of linear thermal expansion from 20° to 1580° C. is 7.6×10^{-6}.

2*c*. The specimen showed slight deformation after completing test.

2*d*. Petrographic examination indicates the corundum grains to have increased in size. A small amount of mullite is also present.

COMPOSITE BEAMS AND SLABS OF HOLLOW TILE AND CONCRETE.

In coöperation with the Hollow Building Tile Association (now the Structural Clay Tile Association, 1400 Engineering Building, Chicago, Ill.), tests have been made to determine the strength of composite beams and slabs of hollow tile and reinforced concrete. The tests were planned to obtain information on the value of the tiles in assisting the concrete to resist shearing and bending failures.

Sixty beams or slabs were fabricated and tested in the bureau's laboratories. Forty-eight of those were composite beams consisting of either one or two reinforced concrete ribs similar to those in ribbed floors of concrete and hollow tile. The remaining 12 were concrete beams, each being similar in design and materials to the concrete portions of some of the composite beams. Some of each type were heavily reinforced

for bending stresses and were tested in a manner to produce shearing failures; others were designed and tested to develop high compressive stresses in the concrete. All beams were 8 inches in depth; those for the shear tests were 6 ft. 4 in. in length and from 4 to 29 inches in width, while those for the bend tests were 15 feet in length and either 8 or 29 inches in width.

The hollow tiles used in the construction of the beams for the shear tests were selected to provide data for the determination of the effect on the shearing strength of the physical properties of the tiles, their weight and number of vertical interior webs. The bend tests were planned to give information on the effects of the weight, number of cells, and arrangement of the tiles on the strength of the beams in bending.

In the construction of the beams no attempt was made to obtain specimens representative of commercial construction. On the contrary, the aim was to obtain specimens of uniform quality as regards the characteristics of the concrete and workmanship in order to minimize variations in the results from uncontrolled causes.

All beams were kept damp for 28 days after construction and were then permitted to dry in the laboratory for approximately two weeks before testing. The average strengths of 6 by 12 inch cylinders representing the concrete of the beams were 2720 lbs./in.^{2} at the age of 28 days and 3070 lbs./in.^{2} at 42 days.

The results of the tests indicated that one row of tiles was equivalent in resisting shear to a concrete rib of the same depth and having a width of from 1.6 to 2.4 inches. These equivalent widths were greatest for the tiles made of the material of the highest strength and modulus of elasticity. However, the tiles made of the weaker materials usually had thicker shells which compensated in part for their weaker structure. At loads considerably less than the maxima the tiles were more effective in increasing the resistance of the beams to bending deformations than at the higher loads. The relatively lower values for the higher loads are believed to be due at least in part to partial failure of the bond between the concrete and tiles. The results of subsequent tests indicated that the method followed in the construction and aging of the beams was not favorable to the development of as strong a bond as would have been obtained with other methods.

A full report of the investigation was published in the *Bureau of Standards Journal of Research*, Vol. 4, No. 6, p. 815 (RP181); June, 1930.

SEPARATION OF COLLOIDAL MATERIAL FROM CERTAIN OHIO SHALES.

The separation of the colloidal material from certain Ohio shales has been completed at the Columbus branch of the bureau. The method used consisted of blunging, sedimentation, supercentrifuging at speeds of 12,000 and 20,000 r.p.m., and filtering through Pasteur tubes.

The material separated at 12,000 r.p.m. centrifuge speed varies from 0.2 per cent. for the Chagrin shale to 11.4 per cent. for the Bedford; the material separated at 20,000 r.p.m. centrifuge speed varies from 0 per cent. for the Chagrin shale to 2.6 per cent. for the Bedford, and the sum of the material separated on the filter varies from 0.05 per cent. for the Chagrin shale to 1.95 per cent. for the Bedford. The quantities obtained for the other eight shales were intermediate between these two.

In a general way the physical properties, slaking time, tempering water, drying shrinkage, and green modulus of rupture all show increases with an increase in the quantity of colloidal matter separable by the above method. The slaking time and tempering water correlate fairly well with colloid content. The Bedford shale shows an unusually high slaking time and an unusually low requirement of tempering water as compared with the others. The correlation between drying shrinkage and modulus of rupture and colloids mechanically separable by the above method is much poorer, however, though in both shrinkage and modulus the increase in their values with increase in separable colloid present is fairly well defined as a general trend from which individual deviations are to be expected.

Work is being continued with the alluvial and glacial clays.

PLATINUM PLATING FOR REPAIRED WEIGHTS.

For many years platinum plating was generally considered of doubtful value for weights. The character of the plating

done by different firms differed widely, the platinum coating was likely to be very porous, and the weights tended to gain excessive amounts.

Within the past few years there appears to have been considerable improvement in the general character of platinum plating. In particular, sets of one-piece weights have shown very satisfactory behavior on boiling in distilled water, and on short time tests of constancy under good atmospheric conditions.

These improvements induced the bureau about two years ago to try platinum plating on some old sets of ordinary analytical weights that were in need of repair. These weights were of the usual screw-knob type, and some trouble was experienced because of failure to thoroughly wash out the cavity under the knob. Such trouble, however, may be experienced from any kind of electroplating on weights of this type.

Thirteen sets of these weights, repaired at various times, have been retested during the past 3 months. All but three sets had been in use under fairly good conditions, since the weighing rooms where they were used are separate from the laboratories. The three unused sets had been kept in the stock room for about 6 months.

The unused sets showed no significant changes, the maximum apparent change being 0.03 mg. There is some doubt as to whether many sets are likely to show this degree of constancy even under these conditions.

Weights of the sets which had been regularly in use showed a marked tendency to gain. There were no significant losses even in sets which had been used to such an extent that losses normally would be expected through wear. About 30 per cent. of the weights gained nearly or over 0.1 mg. The two largest changes were those of two 100 g. weights one of which gained 0.4 mg. and the other 0.8 mg.

These results do not prove that platinum plating causes a greater tendency to change than would be caused by plating with other metals, but they do show conclusively that platinum plating cannot be relied on to produce constant weights. Any plated weights, no matter what plating is used, must be carefully checked for constancy.

Porosity of the brass, resulting in surface spotting of many of these weights, may account for some of the tendency to change. Therefore, there is danger in electroplating old weights, especially old lacquered weights, because they may be made of porous metal. Moreover, some of the weights tarnished without any definite evidence of porosity while some weights gained serious amounts without any evident tarnishing or spotting. Among the latter was one set that had been plated at the bureau.

In repairing old sets, the advantages of platinum plating may sometimes outweigh the danger of inconstancy, especially where the weights can be recalibrated often enough to insure the accuracy of the values used. The experience with these weights shows, however, that danger of some inconstancy must be included in the consideration of advantages and disadvantages.

NEW CONSISTOMETER FOR MEASURING PROPERTIES OF GREASES AND OILS AT LOW TEMPERATURES.

The July number of the *Bureau of Standards Journal of Research* will contain a description of a simple and rugged consistometer which is speedy in operation and which can be employed for either opaque or clear materials of a wide range of consistencies. It also possesses two features which are unusual in a consistometer, but which are of great importance in the testing of all such plastic materials as show a breakdown of structure with working, or which change in consistency with time.

The first of these features is that the test material may be passed successively back and forth through the capillary any number of times. The second is that determinations of the rate of flow are made by passing only a very small volume of material through the capillary, thus minimizing the breakdown effect of the working which is incident to the measurement itself.

With the aid of these two features the unworked, as well as the thoroughly worked, consistency of the material may be closely approximated. With such forms of instrument as permit flow in one direction only, and for which a large amount of material must be passed through the capillary for a single

datum point, neither the unworked nor the worked consistency is obtained, but only an intermediate consistency on partially worked and constantly changing material. The first of the two special features also makes it possible to obtain flow-pressure graphs at a number of temperatures, with a single filling of the instrument, or without removing the instrument form the bath. There are no weighings to be performed and no auxiliary apparatus is required, such as pressure tanks, pressure regulators, etc. The instrument can also be used to measure accurately the viscosity of simple viscous liquids up to many thousands of poises. Most viscometers are suitable only for materials of less than about a hundred poises.

Many plastic materials such as jellies, clay slips, greases, pastes, etc. show a more or less pronounced breakdown of structure and consequent loss of "body" when they are worked mechanically. For such materials the unworked consistency of the undisturbed substance, and the thoroughly worked consistency of the completely brokendown material are, in general, of vastly greater importance than the variable consistency which the material possesses in any intermediate condition. For example, when starting an automobile engine in cold weather, the amount of resistance to flow which the oil offers before its plastic structure is broken down is an important consideration in the proper lubrication of the working parts of the machine. After the machine has been running a few minutes the plastic structure of the oil is destroyed, and the consistency of the worked or brokendown product is the important feature. The consistency of the oil in between times is of slight importance, yet it is this consistency which is measured when a freshly cooled oil is subjected to a single passage through a capillary, as is frequently the case in determining consistency by many old style instruments.

The present paper gives flow-pressure graphs illustrating how the new instrument may be employed to approximate closely the unworked consistency and to measure accurately the thoroughly worked consistency of plastic oils at 0° C. Such oils at this temperature were found to behave like jellies and gelatins in that they continued to increase in stiffness for many hours after all the oil had acquired the temperature of

test. Certain oils also were found to possess marked thixotropic characteristics, that is to say, they partially regained their former structure and high resistance to flow when they were merely allowed to stand undisturbed for a period after a thorough mechanical working.

EFFECT OF VARYING DEVELOPMENT UPON RESOLVING POWER AND SENSITIVITY OF PHOTOGRAPHIC PLATES.

Special developers recommended for reducing the graininess of photographic images are all based on increasing the solvent action of the solution on silver bromide, and decreasing the reduction potential, thus tending to make their action more like the physical developers in which the silver of the image is supplied by the solution. A number of these developers have been compared with ordinary metolhydroquinone and pyrogallol formulas for usefulness in spectrography and other applications involving fine details of the image. Three emulsions were tested for sensitivity and resolving power when developed with each of the developers, and practical spectrographic tests were made with one of the plates. As determined by a parallel-line test object, only developers of very low reduction potential and low rate of development improved resolution to any appreciable extent, and these have no practical value because they reduce the speed of the emulsions. The "borax" developers recommended for motion picture film are at least equal to the standard formulas on the basis of sensitivity and resolution. The tests here applied appear to have little or no bearing on the pictorial use of special developers to reduce "graininess."

This work will be discussed at greater length in the July number of the *Bureau of Standards Journal of Research.*

PERFORMANCE CHARACTERISTICS OF TWO-BLADE PROPELLER FANS.

Some time ago an investigation was undertaken of the performance of two-blade propeller fans, to obtain data needed by the industry. Recently there has been a trend toward the use of fans of this type in cooling-tower installations, and their use has been considered for other applications where it is

desired to move large volumes of air against relatively low pressures. Since no data were available as to the operating characteristics of two-blade propeller fans, the importance to the manufacturer and user of obtaining this information is obvious.

Seven two-blade propeller fans, 8 feet in diameter and of pitch diameter ratios 0.250, 0.375, 0.500, 0.625, 0.938 and 1.063, respectively, were tested under operating conditions approximating those encountered in cooling towers. Each fan was operated at constant speed of rotation against resistance conditions which were varied by steps, from a completely blocked passage to as nearly an open passage as the conditions in the test duct permitted. The volume of air moved in unit time, the head developed, and the power absorbed by the fan were determined for each resistance condition. Data were obtained for two conditions of operation: (1) with the fan operating as a blower, and (2) with the fan exhausting air from the test duct.

The results were expressed in the form of coefficients and plotted to facilitate their use in estimating the performance of fans of other diameters and of other rotational speeds.

The chief effect of variation of pitch diameter ratio is to increase the range of the head and volume coefficients with increase in pitch diameter ratio, up to pitch diameter ratio of 0.938. Pitch diameter ratios greater than 1.0 should not in general be used.

Two-blade propeller fans are suitable for moving large volumes of air against pressures that do not exceed 1.0 inch of water. For pressures greater than 1.0 inch of water the rotational speeds become inconveniently large. The speed of rotation and the fan diameter should be carefully chosen to obtain maximum efficiency.

This work will be fully reported upon in the July number of the *Bureau of Standards Journal of Research.*

AIRCRAFT RADIO RESEARCH.

Experiments are in progress at the bureau on improvements in methods of adjusting the directions of the courses produced by range beacon transmitters to fit airways intersecting at any angles. The aim is to change from the simple

90° or 180° adjustments to other angles without material loss of distance range. Apparently this can be accomplished by the use of a short vertical antenna on the central supporting mast of the loop antennas. In order to avoid loss of sharpness of course indication, careful attention has to be given to the coupling arrangement to this antenna, its position on the mast, the phases of currents in it and in the loop antennas, and the presence and location of metal parts or electric light wires on the mast.

Further development of the radio system for blind landing has been in progress for the past two months. Various combinations of the three elements making up the blind landing system have been tried at College Park, Md. A runway localizing beacon and a high-frequency landing beam transmitter have been placed at one end of the flying field with the localizing beacon course and the landing beam directed along the major runway of the field. A marker beacon is installed at the other end of the field. The angle and transmitted power of the high-frequency landing beam has been adjusted so that an airplane may be guided along the proper gliding path to the field and may land at the proper point on the runway. Experimental work is now being directed to the runway localizing beacon and the marker beacon.

The use of the runway localizing beacon has previously proved difficult because of the necessity for adjusting the receiving set volume control as the airplane is approaching the beacon transmitter. Experiments facilitating the use of the runway localizing beacon through the development of a suitable device for automatically controlling the intensity of the receiving set output signals are in progress. A device of this type would permit the pilot to use the localizing beacon all the way to the point of landing instead of having to abandon it when within one-half to one mile of the point of landing (the volume adjustment then becoming too critical) and having to maintain the course (along which the localizing beacon has oriented him) by other means.

The experimental work on the marker beacon is to determine whether an aural or visual type best meets the requirements. Present results indicate that the aural type of marker beacon is preferable, for this particular purpose, since this relieves the pilot of watching an additional instrument.

RADIO SIGNAL TRANSMISSIONS OF STANDARD FREQUENCY, JULY TO DECEMBER, 1930.

The bureau announces a new schedule of radio signals of standard frequencies, for use by the public in calibrating frequency standards and transmitting and receiving apparatus. The signals are transmitted from the bureau's station WWV, Washington, D. C. They can be heard and utilized by stations equipped for continuous-wave reception at distances up to about 1,000 miles from Washington,

The transmissions are by continuous-wave radio telegraphy. A complete frequency transmission includes a "general call," "standard frequency signal," and "announcements." The general call is given at the beginning of each 12-minute period and continues for about 2 minutes. This includes a statement of the frequency. The standard frequency signal is a series of very long dashes with the call letter (WWV) intervening; this signal continues for about 4 minutes. The announcements follow, and contain a statement of the frequency being transmitted and of the next frequency to be transmitted. There is then a 4-minute interval while the transmitting set is adjusted for the next frequency.

Information on how to receive and utilize the signals is given in Letter Circular No. 280, which may be obtained by applying to the Bureau of Standards, Washington, D. C. Even though only a few frequencies are received (or even only a single one), persons can obtain as complete a frequency meter calibration as desired by the method of generator harmonics, information on which is given in the letter circular. The schedule of standard frequency signals is as follows:

Eastern Standard Time.	Frequency in kilocycles.					
	July 21.	Aug. 20.	Sept. 22.	Oct. 20.	Nov. 20.	Dec. 22.
10.00 P.M....	1,600	4,000	550	1,600	4,000	550
10.12.....	1,800	4,400	600	1,800	4,400	600
10.24.....	2,000	4,800	700	2,000	4,800	700
10.36.....	2,400	5,200	800	2,400	5,200	800
10.48.....	2,800	5,800	1,000	2,800	5,800	1,000
11.00.....	3,200	6,400	1,200	3,200	6,400	1,200
11.12.....	3,600	7,000	1,400	3,600	7,000	1,400
11.24.....	4,000	7,600	1,500	4,000	7,600	1,500

International Exposition of Liege, 1930. The international exposition organized to celebrate the centenary of the independence of Belgium which is now in progress includes a large and diversified number of congresses and conventions. The participants in these activities are representative of leadership in various fields of science and industry of both hemispheres. A pamphlet recently published, contains the programmes of these meetings with the names of their presiding officers. Sixty-eight conventions are there listed on a large number of important industrial and professional subjects. Present-day world-wide activity in science is well demonstrated by this document and it is safe to say the proceedings themselves will represent the true pulse of modern science and technology.

L. E. P.

THE FRANKLIN INSTITUTE.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meetings, Board of Managers, May 28 and June 25, 1930.)

RESIDENT.

MR. EARLE G. BOYER, President, Earle G. Boyer, Inc., Second and Fishers Avenue, Philadelphia, Pa. For mailing: 6944 Cresheim Road, Philadelphia, Pa.

MISS ELIZABETH LONG CLAIR, Chemist, "Chemistry Leaflet." For mailing: 317 Euclid Avenue, Ambler, Pa.

MR. JOHN GARDINER, JR., Retired. 2100 Washington Avenue, Philadelphia, Pa.

MR. SAMUEL E. JOLLY, Chemist, 468 Chester Pike, Sun Oil Company, Norwood, Pa. For mailing: 633 Tenth Avenue, Moores, Pa.

MR. H. ENNIS JONES, Banker, Franklin Trust Company, S. W. corner Fifteenth and Chestnut Sts., Philadelphia, Pa.

MR. OTTO V. KRUSE, Hydraulic Engineer, 614 Atlantic Building, Philadelphia, Pa.

DR. JOSEPH LEIDY, II, Medicine, 1713 Walnut Street, Philadelphia, Pa.

MR. MORTON GIBBONS-NEFF, Insurance, 127 South Fifth Street, Philadelphia, Pa.

NON-RESIDENT.

MR. THOMAS D. M. CARDEZA, 43 East Forty-ninth Street, New York City.

MR. RAYMOND L. DREW, Chemist, American Dyewood Company, Belleville, N. J. For mailing: 33 Livingston Avenue, Arlington, N. J.

MR. NORMAN R. GIBSON, Civil Engineer, Vice-President and Chief Engineer, Buffalo, Niagara and Eastern Power Corp. The Niagara Falls Power Company, 600 Electric Building, Buffalo, N. Y.

MR. GEORGE W. GREENWOOD, Industrial Engineer, S. F. Whitman and Son, Inc., Philadelphia, Pa. For mailing: 902 North Harrison Street, Wilmington, Del.

MR. HEYMAN ROSENBERG, Designing Mechanical Engineer, Vice-President, Parker-Kalon Corporation; President, Hyro Manufacturing Company, Inc., 200 Varick Street, New York City.

MR. HARRY M. VALE, Investor, 350 Madison Avenue, New York City. For mailing: Southern Pines, N. C.

MR. LEWIS WETZEL, Civil Engineer, 1017 Calvert Street, Baltimore, Maryland.

CHANGES OF ADDRESS.

MR. GEORGE L. ANDERSON, Delafield, Wis.

MR. ONWARD BATES, 832 Belden Avenue, Chicago, Ill.

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NECROLOGY.

Mr. W. H. Bristol, Waterbury, Conn.

Mr. Samuel M. Felton, Chicago, Ill.

Dr. Elmer A. Sperry, Brooklyn, N. Y.

LIBRARY NOTES.

RECENT ADDITIONS.

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BOOK REVIEWS.

PERIODISCHES SYSTEM. Geschichte und Theorie. Dr. E. Rabinowitsch and Dr. E. Thilo. 8vo, xii–302 pages, illustrations and tables. Stuttgart, F. Enke, 1930. Price, 29 marks.

Vast indeed is the change that has been made in the fundamental conceptions of the structure of chemical compounds as a result of the researches of the last quarter-century. When we consider the comparatively brief period in which the revolutionary work has been performed and the enormous and complicated mass of data produced, we can appreciate the labor that is needed for the production of a comprehensive volume such as that now under consideration.

The preliminary part of the book is devoted to an interesting account of the earliest known views as to the structure and nature of substances. The literature of India now available, it is stated, as remote as the 15th century before the present era, shows some traces of speculations as to the nature of things, but not with the materialistic attitude necessary to the study of tangible objects. Shortly before the date assigned as the beginning of the present era, an Indian philosopher advanced views somewhat similar to those of the very early Greek philosophers, but it is not impossible that some of this Hellenic-like speculation had filtered into the land of Buddha and Brahma, as oriental philosophy had in considerable measure invaded Hellenic areas.

Sydney Smith spoke of "Those confounded ancients, who anticipated everybody," No more remarkable instance can be found than the development of the atomic theory by Leucippus and Democritus in the fifth century before the beginning of the Christian era. A result of deduction only, the theory even included a kinetic phase, for the properties of compounds were ascribed not only to the arrangements of atoms but also to the motions mutually exercised. These theories were later carried further by Epicurus and by his apostle Lucretius, in the high and palmy state of Rome. The atomic theory remained, however, for many centuries without special influence on practical science. This condition was largely due to religious influence. Greek culture, spread widely over the near East by the conquests of Alexander, had begun to influence even the Jews, who were in the main strongly resistant to foreign cults. Dominant Jews saw peril in such invasion, as likely to lead to the spread of animistic cults and nature worship among their people, so by strong effort, they shut off all tendency to nature study. Christianity, arising wholly in a Jewish environment, entered the Greek world with this handicap and thus progress in the physical and natural sciences was delayed about a thousand years, true science not marching, but mostly marking time.

The revival of learning broke this idleness. Many epoch-making discoveries followed rapidly. The fourth era of Kopp's classic history began, that of quantitative analysis. In the early part of the 19th century, Dalton's presentation of atomic theory served to give definite purpose to chemical statics. Dalton indeed, is not entitled to all the honor in this case, for several workers had already advanced similar views. This, however, is a common difficulty in studying any phase of human progress. It is almost always impossible to find a first investigator.

For nearly a century chemists held to the view that each element in the free

state consists of minute particles, indivisible, indestructible and incapable of conversion into any other elementary form. All these views have gone by the board. The atom is a complex group of electrified particles, most of which are in motion around a nucleus after the fashion of the members of the solar system in their relation to the sun. Not long ago, a distinguished investigator in this field lectured on "The Astronomy of the Atom."

The dead past must bury its dead. Old lamps must be exchanged for new even if the power to call spirits from outer darkness is surrendered. While experience shows that all that great men preach and teach may not hold for aye, yet much does. Modern chemistry will have to solve questions in statics and dynamics on the basis of the complex atom with its susceptibility to disintegration and transmutation. The book in hand will suffice fully to bring to the student all necessary information concerning the present theoretical views, setting them forth in the technical form and elaborate language of the well-developed science. The text is well written and well printed. The book is an excellent specimen of book-making and will be a most useful addition to the library of research laboratories and of students of physical chemistry. The metals of the rare earths (57–71) are not specifically discussed. They are enumerated in two tables of the periodic system (pp. 44, 46). In the former, a typographic error gives Ca for cerium and in both, 71 is given as Cp (cassiopeium) instead of Lu (lutecium) an inadvisable substitution.

In looking over such a work, the question occurs as to how far these abstruse and highly specialized theories may influence the practical phases of chemistry. Among the very large class of workers who are engaged in research in applied chemistry or in routine industrial or commercial analysis, very little interest is shown in the results of physical chemistry. In the practical field the atom is still the unit of chemical action. The assayer seeking the amount of gold in a rock, the toxicologist seeking to find a poison, the works-chemist seeking to discover why a fabric fails to take the dyestuff properly, will pay no attention to the space-lattices of the compounds with which they are concerned. Nevertheless, it is by equal cultivation of theory and practice that safe progress is made, and we cannot foresee how far the modern theories will ultimately modify even the simplest laboratory procedure. "Die Weltgeschichte ist das Weltgericht."

HENRY LEFFMANN.

ANNUAIRE TECHNIQUE DE CAOUTCHOUC DE LA GUTTA-PERCHA, including the Industries belonging thereto. Small octavo, 200 pages, paper bound, A.-D-Cillard, Paris, 49 francs.

This work comprises full information in regard to rubber and gutta-percha and similar plastic materials. The various manufactures are classified, great care having been taken to get accurate information not only from France but from foreign countries. A considerable part of the work if devoted to the nature of these materials, giving their composition, properties and principal applications. The publication is interspersed with a considerable number of brilliantly colored advertising sheets which do not add to its attractiveness.

H. L.

UNION GEODESIQUE ET GEOPHYSIQUE INTERNATIONALE. Section de Magnetisme et Electricite Terrestres. Comptes Rendus de l'Assemblee de Prague, Septembre 1927. Imprimes par les soins de Ch. Maurain, Secretaire de la Section et Directeur du Bureau Central, 269 pages, map, 8vo. Paris, Les Presses Universitaires de France, 1929.

The rapid growth of the movement for international coöperation in investigation in terrestrial magnetism and electricity is well demonstrated by the large number of contributions recorded in this bulletin, made by leading authorities in these subjects, from every quarter of the world. Besides a full report of the proceedings and minutes of this meeting, reports and communications on numerous phases of these subjects are included. The subject matter has been edited by Mr. J. A. Fleming, Assistant Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and General Secretary of the American Geophysical Union, Mr. Louis A. Bauer who was secretary at the Prague meeting and at the close of the session elected President of the section, being unable through illness to perform this task as originally contemplated. To the constantly increasing number of men of science who are interested in terrestrial and even cosmic electrical and magnetic phenomena this collection of reports on recent research in these subjects should prove of rare value and interest.

L. E. P.

IN THE REALM OF CARBON. The story of organic chemistry. By Horace G. Deming, University of Nebraska. 365 pages, numerous illustrations, and full-page plates, 8vo. John Wiley and Sons, Inc. New York, 1930, $3.00.

This is one of a type of books that have become popular in late years, intended to bring a knowledge of the facts of modern chemistry to the general public and to that somewhat vague individual known as "the man in the street." Several American writers have been quite successful in this field, having dealt with chemistry in a rather broad way and in its industrial applications. The present work is limited to that section of chemistry still called "organic," though it has long been known that the general principles of that phase of the science are identical with those in the inorganic field. Notwithstanding this identity it is not practicable to treat organic chemistry in direct association with its relations to inorganic.

Carbon, being the characteristic element of organic substances has led to organic chemistry being called the chemistry of the carbon compounds. The distinction between organic and inorganic compounds was broken many years ago by Wöhler, discoverer of the synthesis of urea. Many hundreds of organic compounds are now easily obtained by ordinary laboratory methods, and in fact, the great bulk of the compounds now included in the descriptive chemistry are not produced in living organisms, many of them being wholly antagonistic to vital action.

In preparing a book on organic chemistry intended for the general reader the author is faced with the difficulty of determining how much to include and how to avoid running into the more abstruse problems that have arisen of late years. The choice made by a particular author will have to be regarded as satisfactory, so that the reviewer does not intend to devote any space to suggestions as to matters that should have been omitted or others that should have been included.

The work begins with a brief account of the early history of chemistry but the description soon passes to conditions subsequent to the revival of learning. A few pages are devoted to a brief but commendable summary of the progress of the science through the latter half of the 18th and the first half of the 19th centuries, this period being closely contemporaneous with Kopp's 4th period, that of quantitative analysis. In this era the work of Berzelius is especially noticeable. The chapter on atoms and molecules gives, of course, the usual notice of the remarkable development of the atomic theory by the Greeks. Unfortunately, we have but small fragments of the writings of these men, but at a later period the Epicureans favored the theory strongly. In this connection the mind reverts to the story in Acts about the Epicurean and Stoic philosophers who discussed theology and morality with Paul. We, unfortunately, have no record of the discussions but it would be certainly interesting to know whether the Epicureans attempted to apply the principles of the atomic theory to the solutions of cosmic problems. About the first century of the present era the Roman philosopher and poet, Lucretius, who was a follower of Epicurean philosophy as Horace was of Epicurean ethics, gave in some detail the applications of the atomic theory to the general principles of chemical combinations. He compares the atoms of the elements to the letters of the alphabet and the compounds to the words of a language, a method of illustration which is still in use.

Passing from these historical discussions, the general principles of organic chemistry as now understood, are set forth in simple language and interwoven neatly with theoretical material; the many applications which have developed from research are presented in vivid form to the reader, thus the value of theory and the necessity for constant coöperation between it and practice are exemplified. Many examples of structural formula are given. Modern research, is plentifully set forth, and illustrations of important industrial procedures are used. There is also, a series of full-page plates in which the imagination has been allowed a moderately free reign. One of the most interesting is the picture of Kekulé, seated in an easy chair watching the flames of a soft coal fire, in which the hexagon appears. The book is well printed on excellent paper, contains a very large amount of information and will be very useful to the general reader, and even of considerable interest and value to the student beginning the serious study of organic chemistry.

HENRY LEFFMANN.

DIELECTRIC PHENOMENA—ELECTRICAL DISCHARGES IN GASES. By S. Whitehead, B.A. Edited with a preface by E. B. Wedmore, M.I.E., F. Inst. P., 175 pages, 42 diagrams, 12mo. New York, D. Van Nostrand Company, Inc. Price $4.00.

The rapid development of high-tension distributing systems for electricity has served to attach increasing importance to the study of dielectric phenomena. In this volume, S. Whitehead has devoted his attention to one particular phase of the subject—Electrical Discharges in Gases.

Because of the immense importance of this subject in the industrial field, further research is now being encouraged by the Electrical Associations. Through this book the author renders valuable aid by collecting and summarizing the data dealing with this subject. It is interesting to note that the number of empirical

equations which have been developed for the purpose of explaining and predicting the behavior of the several types of electrical discharges. Yet, there arises the early realization that many factors still are unknown and not accounted for and that much of the available information remains unrelated and not susceptible to interpolation.

The subject matter has been arranged under three general headings: (1) Introduction (Discharges in General), (2) Sparking, and (3) Corona. Under Appendices will be found descriptions and derivations of mathematical formulas dealing with the subject of discharges through gaseous dielectrics. The book should be extremely valuable as an introduction to and reference for the study of electrical discharges in gases.

T. K. CLEVELAND.

ASTRONOMY. AN INTRODUCTION. By Robert H. Baker, Professor of Astronomy in the University of Illinois. 504 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1930. Price $3.75.

Star-gazing has been an occupation of mankind from a very early period. It would seem that as soon as the human being reaches a condition of conscious appreciation of the environment the sights of the sky would invite attention. However, this may be, we know that astronomy is an ancient science. Heavenly bodies bear in their names clear evidence of the study of them in the days of mythology, and even today many intelligent persons believe in the influence of the stars upon the course of individual life and hold them to be more or less prophetic in their indications.

Modern works on astronomy, such as the book before us, pay no attention to astrology but deal with the purely scientific features of the study of stars. Much progress has been made in astronomy of late years, aided particularly by the application of photography and telescopes of high power. After a general presentation of the aspects of the sky and a description of some of the larger telescopes and their housings, the earth is studied in its cosmic relations, followed as usual, by descriptions of the sun and its attendant planets, asteroids and satellites. It is worth noting that in speaking of the moon the author very positively asserts that its orbit is always concave to the sun. This corrects a widespread error, not only of people at large, but presented even diagramatically in a work published a few years ago by a British astronomer. On one point the reviewer must speak in slightly unfavorable criticism. In the section on Mars, we must, of course, expect some words about the Martians. This interesting planet, with its obvious resemblance to our own earth in some respects, notably in the markings and in the polar caps, has always been a point of speculation. As a matter of fact, we have no data whatever upon which to base judgment as to whether Mars is inhabited by intelligent beings nor can we make any statement concerning any other of the many millions of celestial bodies. In the first place we do not know the limits of life. We have only one phase of life before us. Living organisms, that is, beings that have consciousness and the powers of reproduction may be constituted upon an entirely different foundation than that of the beings around us. The only position that the honest scientist can take in this matter is to give it up. In the case of Mars, the public mind has been seriously misled by the lack of critical attitude on the part of the astronomers. To a great extent, this has been due to the writings of the late Percival Lowell

aided by an erroroneous translation of an Italian work. The Italian astronomer, many years ago, called the markings "Canali" in his own language, which means "channels" and not "canals." The dangerous suggestiveness of the latter translation is obvious. It is sure to convey the idea of artificial construction which the proper word does not. No astronomer should use the word "canals" for the markings on Mars. Dr. Baker calls attention to this mistranslation, but notwithstanding uses the word "canals" in many places.

In the latter part of the book, the reader is taken outside of the comparatively narrow limits of our universe, known as a "Galaxy" because dominated by the Milky Way. We are given the information about these innumerable distant universes which the telescope is now revealing. Attention is also given to the subject of double stars, nebulæ, comets and meteorites. On page 287 it is stated that helium was discovered in the spectrum of the prominences during the total solar eclipse of 1868. The reference is probably to Jannsen's contribution to *Comptes rendus*, but in that article no reference is made to the discovery of an unusual bright line. There is a curious mystery about helium, that is as to when it was named, although there is little doubt that Lockyer invented the term. It is unfortunate that he assumed a metallic nature, for "helion" would be a better name.

The book is a very excellent summary of modern astronomy, suitable for the general reader and for the student, excellently printed, liberally illustrated and text well written. It can be well recommended, therefore, as a highly commendable and timely publication.

HENRY LEFFMANN.

WORKED EXAMPLES IN ELECTRICAL TECHNOLOGY. By F. Peasgood, A.M.I.E.E., and H. J. Boyland, A.M.I.E.E. Lecturers in Electrical Engineering at the Northampton Polytechnic Institute, London. xv–219 pages, 8vo. cloth, New York, Oxford University Press, 1929, Price $5.00.

As with the demonstration of a mathematical theorem, the mode of attack in the solution of a problem of design has usually a most important bearing upon the ease with which the required results may be found; facility and expedition in the application of analytical methods are acquired by the solution of many and diversified problems. The effort is an important one that should be guided with care lest the student may have something to unlearn when he has finished his course. A collection of worked examples is obviously a most effective method both to acquire experience in design and the habit of orderly arrangement of work.

The examples which are contained in the present volume cover a wide range of topics in electrical technology and are graded in conformity with the requirements of students who are candidates for the B.Sc. (Engineering) degree for Associate Member of the Institution of Electrical Engineers or similar credits. The topics are grouped under three headings, the direct current circuit, the magnetic circuit, the alternating current circuit. Electrical quantities which are not readily visualized here appear in their final arithmetic values with all the steps of the computation given in a model form of procedure. Many well-made line cuts and graphs accompany the text, and at the end of each section an ample number of additional unworked exercises is provided.

The work is a valuable volume for collateral reading on sound procedure and orderly arrangement of work in electrical design. L. E. P.

THE PROVINCE OF NEW BRUNSWICK, CANADA, ITS NATURAL RESOURCES AND DEVELOPMENT. By L. O. Thomas, B.Sc. 167 pages, illustrations, maps, 8vo. Ottawa, Canada, Department of the Interior. 1930.

The potentialities of this maritime province have undoubtedly been overlooked during the period of the agricultural development of Western Canada and the industrial growth of Ontario and Quebec, for it is only recently that its water-powers and forest wealth have been utilized in large-scale pulp and paper enterprise. Progress in this direction has indeed been remarkable. Last year the largest power site in the Maritimes was developed at Grand Falls, with an installation of 60,000 horse-power and transmission line of 104 miles to Chaleur bay; 5,500 horse-power was added to the 9,000 horse-power already developed on the Nipisiguit; the capacity of the plants at Edmundston and Bathurst were enlarged; while a newsprint mill with an initial daily capacity of 250 tons came into operation in March, 1930; and a bleached sulphite mill at Athol has lately been completed.

A similar awakening is in evidence in regard to the fertile and cheap agricultural lands, minerals and fisheries, and the many recreational attractions of the province, all of which resources and the development opportunities they present are dealt with in this governmental publication.

R.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 342. Effect of Turbulence in Wind Tunnel Measurements. By H. L. Dryden and A. M. Kuethe. 26 pages, illustrations, quarto. Washington, Government Printing office, 1930. Price ten cents.

This investigation was carried out at the Bureau of Standards at the request of and with the financial assistance of the Committee. The paper gives some quantitative measurements of wind-tunnel turbulence and its effect on the air resistance of spheres and airship models, measurements made possible by the hot wire anemometer and associated apparatus developed at the Bureau of Standards. The apparatus in its original form was described in Technical Report No. 320 and some modifications are presented in an appendix to the present paper.

One important result of the present work is a curve by means of which measurements of the air resistance of spheres can be interpreted to give the turbulence quantitatively. Another is the definite proof that the discrepancies in the results on the N.P.L. standard airship models are due mainly to differences in the turbulence of the wind tunnels in which the tests were made.

An attempt is made to interpret the observed results in terms of the boundary layer theory and for this purpose a brief account is given of the physical bases of this theory and of conceptions that have been obtained by analogy with the laws of flow in pipes.

Report No. 343. Effect of Variation of Chord and Span of Ailerons on Rolling and Yawing Moments at Several Angles of Pitch. By R. H. Heald, D. H. Strother, and B. H. Monish. 29 pages, illustrations, quarto. Washington, Government Printing Office, 1930. Price fifteen cents.

This report presents the results of an extension to higher angles of attack of the investigation described in Reference 1, of the rolling and yawing moments due to ailerons of various chords and spans on two airfoils having the Clark Y and U. S. A. 27 wing sections.

The measurements were made at various angles of pitch but at zero angle of roll and yaw, the wing chord being set at an angle of +4° to the fuselage axis In the case of the Clark Y airfoil the measurements have been extended to a pitch angle of 40°, using ailerons of span equal to 67 per cent. of the wing semispan and chord equal to 20 and 30 per cent. of the wing chord. It is planned later to extend the investigation to hinge moments of the ailerons for the conditions covered in the rolling and yawing moment tests.

The work was conducted in the 10-foot wind tunnel of the Bureau of Standards on wing models of 60-inch span and 10-inch chord.

Report No. 344. The Design of Plywood Webs for Airplane Wing Beams. By George W. Trayer. 17 pages, illustrations, quarto. Washington, Government Printing Office, 1930. Price ten cents.

This report of the Forest Products Laboratory deals with the design of plywood webs for wooden box beams to obtain maximum strength per unit weight. A method of arriving at the most efficient and economical web thickness, and hence the most suitable unit shear stress, is presented and working stresses in shear for various types of webs and species of plywood are given. The questions of diaphragm spacing and required glue area between the webs and the flange are also discussed.

PUBLICATIONS RECEIVED.

In the Realm of Carbon. The story of organic chemistry, by Horace G. Deming, Professor of Chemistry, University of Nebraska. 365 pages, illustrations, plates, portraits, 8vo. New York, John Wiley and Sons, Inc., 1930. Price $3.00.

La Gamme introduction a l'étude de la musique, par P. J. Richard. Preface de M. Marius Casadesus. 231 pages, illustrations, 12mo. Paris, Librairie Scientifique Hermann et Cie, 1930. Price, in paper, 28 francs.

Astronomy. An introduction by Robert H. B. Baker, Ph.D. 521 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1930. Price $3.75.

Manuel de Réception Radio-Électrique, par Pierre David, Dr. ès Sc. 308 pages, illustrations, 8vo. Paris, Masson et Cie., 1930. Price, in paper, 36 francs.

Les Rayons X (Theorie et applications), par Jean Thibaud. Collection Armand Colin (Section de physique). Paris, Librairie Scientifique Armand Colin, 1930. Price 10 francs 50.

Physique Moderne. Exposé synthétique et méthodique de la physique d'aujourd'hui et des travaux théoriques et experimentaux des plus grand physiciens contemporains, par Ing. Gaetano Castelfranchi. Traduction française par M. A. Quemper de Lanascol. 660 pages, illustrations, 8vo. Paris, Librairie Scientifique Albert Blanchard, 1930. Price 70 francs.

The Province of New Brunswick, Canada, its Natural Resources and Development, by L. O. Thomas. Department of the Interior, Ottawa, Canada. Natural Resources Intelligence Service. 167 pages, illustrations, map, 8vo. Ottawa, King's printer, 1930.

Storage Batteries. A general treatise on the physics and chemistry of secondary batteries and their engineering applications by George Wood Vinal. Second edition, rewritten and reset. 427 pages, illustrations, 8vo. New York, John Wiley and Sons, Inc., 1930. Price $5.00.

Periodische System, Geschichte und Theorie, von Dr. Eugen Rabinowitsch und Dr. Erich Thilo. 302 pages, illustrations, 8vo. Stuttgart, Ferdinand Enke, 1930. Price, in paper, 27 marks, cloth 29 marks.

Leçons sur les Conduites, par M. Charles Camichel. 101 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie, 1930. Price 30 francs.

The Adjustment of Errors in Practical Science, by R. W. M. Gibbs. 112 pages, illustrations, 12mo. Oxford University Press, 1929.

Achema Jahrbuch, Jahrgang 1928-30. Berichte für Stand und Entwickelung des chemischen Apparatewesens. Herausgegeben unter Mitwirkung von Fachgenossen aus Wissenschaft und Technik, von Dr. Phil., Dr. Ing., e.h. Max Buchner, Hannover. 260 + 64 pages, illustrations, 12mo. Hannover, Dechema, 1930. Price 10 marks.

Annuaire Technique du Caoutchouc de la Gutta-Percha et des Industries qui s'y rattachent accompagné d'un répertoire des produits chimiques. 192 pages, illustrations, 8vo. Paris, A. D. Cillard, no date. Price 49 francs.

Matter and Radiation with Particular Reference to the Detection and Uses of the Infra-red Rays, by John Buckingham, M.A. 144 pages, illustrations, plates, 8vo. New York, Oxford University Press, 1930. Price $3.00.

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CURRENT TOPICS.

The Possibility of Experimentally Investigating the Upper Layers of the Atmosphere. H. BENNDORF. (*Phys. Zeit.*, March 1, 1929.) In this article, which emanates from the physical laboratory of the University of Graz, after a general statement of what is known about the upper regions of the air consideration is given to methods of investigation that involve sound rays. The application of electric waves to the problem is reserved for a subsequent paper.

The atmosphere consists of two rather sharpiy separated layers, the troposphere, reaching on the average to a height of 12 km. above the earth's surface and the stratosphere from this height upwards. In the troposphere there are ascending air currents due to the unequal heating of the earth by solar radiation. In consequence of their adiabatic expansion there is a reduction of temperature with increasing elevation. Because of the constant stirring of the air by the currents its composition does not change noticeably with the height. Since the upper limit of the troposphere roughly coincides with the height attainable by human beings on air craft this part of the atmosphere is directly accessible to investigation. This is not the case with the stratosphere, yet balloons carrying registering apparatus furnish information concerning temperature and humidity up to a height of 30 km., and winds are observable by pilot balloons up to 20 km. Anything else supposed to be known about the stratosphere is deduced from thermodynamics or the kinetic theory of gases or derived from a study of phenomena that take place in that region of the air. Some of these conclusions will now be given.

1. *Limits and Motion of the Atmosphere.* Störmer has shown that occasionally displays of the aurora borealis take place at a height of 1,000 km. This shows that there are traces of matter at this great elevation. Indeed the kinetic theory of gases requires that there be no sharp limit to the air but that it shade off gradually into a very tenuous gas. A few observations of the trails of meteors and of luminous night clouds indicate the presence of air currents at high altitudes. In the northern hemisphere from 30 to 80 km. above the earth east winds prevail while above them are west winds.

2. *Temperature of the Atmosphere.*—Registering thermometers carried by balloons have shown that in the lower layers of the stratosphere up to about 30 km. there is a constant temperature of 220°

abs. (−53° C.). Meteorologists had believed that this temperature prevailed throughout the stratosphere, but the arrival of fresh information has led to the conclusion that in the region from 40 to 60 km. there is a layer of warmer air at about 300° abs. Lindemann and Dobson's theory of meteors and observations on the propagation of sound unite in making this probable, while the presence of ozone at an elevation of 50 km. would explain the increase of temperature. For the entire atmosphere the temperature conditions are as follows: In the troposphere the temperature decreases about linearly to 220° abs. Then in the stratosphere it remains constant up to 30 km. It sharply increases to 300° abs. for the range 40 to 60 km. Nothing is known about the temperature at greater heights.

3. *Pressure, Density and Composition of the Atmosphere.*—When the temperature and composition of the air at all heights are known then both the density and pressure can be calculated from formulas. The composition of the troposphere is known. "At present the question of the composition of the atmosphere in its higher regions must be designated as unsolved." Meteorologists used to hold that in the stratosphere the lighter gases were present in proportions that increased with elevation, but this view may need modification. All we know of the composition of the air in the stratosphere comes from the spectroscope when applied to the absorption spectrum of the atmosphere and to the emission spectrum of the aurora and meteors. It is certain that ozone exists there and also nitrogen. From the green auroral line it is inferred that there are traces of oxygen at considerable elevations.

4. *Ionization, Conductivity and Dielectric Constant of the Stratosphere.*—Since ultra-violet radiation from the sun and the penetrating radiation are always acting it is readily seen why the upper layers of the atmosphere are ionized. At times they are aided by a corpuscular radiation from the sun. As a result the conductivity of the air at great elevations is immensely greater than at the earth's surface. Indeed it is calculated to be 10^{13} times as great. The streaming of this conducting air across the magnetic lines of the earth induces currents in it that would account for variations in the earth's magnetic field. Owing to the presence of free electrons in the air its dielectric constant is reduced to below unity. The existence of such a conducting layer at high elevation is confirmed by the observed phenomena of radio transmission.

Most of what is known about the stratosphere has come from observation of natural processes occurring within it and not from experiments conducted upon it. There are three such possible experimental methods of approach: (*a*) shooting projectiles from wide-range canon, (*b*) sounding with beams of sound, and (*c*)

sounding with radio waves. In the Great War German projectiles attained a height of at least 40 km. A series of such trajectories would allow inferences to be drawn in regard to the density of the air and this in turn would lead to conclusions as to temperature. The author does not know whether Germany possesses such data or not.

The author then develops at length the theory of the propagation of sound waves through air at rest and through moving air. Observations made by ear on loud sounds such as cannon fire, accidental explosions and volcanic eruptions, have revealed interesting facts in the distribution of areas of audibility. The sound is heard at all points in an area near to its origin. Beyond this area is the " zone of silence " where nothing is heard. Outside of this is a second area of audibility. The innermost zone of audibility, immediately surrounding the source and having an average radius of 50 km., offers no clue for the investigation of the higher reaches of the air but the outer zone of audibility is of special significance because it is caused by rays that have penetrated to high altitudes and have thence returned to earth. A. Wegener is quoted in this matter. " The outer zone of audibility occurs with great regularity in Europe, in Japan, at the equator and presumably in all latitudes. As a rule the zone, at least for the ear, manifests itself not as a closed ring but as a sector whose outer radii form a variable angle at the center. This angle in a series of cases has been observed to be more than 180°. In several cases the formation of a closed ring has been proved or made probable. As A. Wegener has shown the distances of the outer zone from the center vary greatly with the time of year. In Europe and Japan the inner edge of the outer zone of audibility is situated in January and February at a distance of 110 km. from the center while in August it is 190 km. away. The zone of maximum intensity does not coincide with the inner edge but in the first two months of the year is 125 km. distant from the center and in August is 230 km. removed from the center. The Alps do not shut off the sound rays that form the outer zone of audibility nor do winds in the troposphere have any recognizable influence on the production of the outer zone or on the azimuth of the sector that forms. In some instances there are indications of a second outer zone of audibility."

A series of experiments have been made by exploding munitions of war. The times of the arrival of the sound waves were recorded not by the ear but by apparatus registering optically or mechanically. The interpretation of the results presents great difficulty but one conclusion stands firm " that at elevations between 30 and 50 km. there takes place a rapid increase in the velocity of sound up to

at least 350 m/sec." Air at 306° abs. or 33° C. would transmit sound with this velocity.

The author makes a series of suggestions by which further information concerning the upper air can be obtained by using sound waves.

G. F. S.

Efficiency of Machinists' Vises. H. L. WHITTEMORE and L. R. SWEETMAN. (*Bureau of Standards Jour. Research*, Aug., 1929.) In these days of automatic machines it is quite easy to overlook the importance of simple hand tools that have a long history behind them. "Unless the work is very large, vises are necessarily used to hold it in the position desired by the workman. Because there is nothing spectacular or impressive about machinists' vises, we lose sight of the fact that these gripping devices are a most essential element of our mechanical equipment."

The design of vises has in some cases been founded on strength tests but few investigations have been made to determine what size of vise is the most efficient for a given purpose. The vise itself and the workbench to which it is bolted resist the force applied to the piece held by the vise. This force may be static when it acts for some time as in sawing or filing or dynamic as in the case of hammering. With static forces the size of the vise should be of little importance because the force exerted on the piece is transmitted to the bench and floor but forces of impact act for so short a time that they affect chiefly the vise and the piece. The greater the inertia of the vise the shorter the distance through which it is moved. Anything that will economize the muscular energy of the workman is worth while because this is the most expensive kind of energy used in the shop.

Three types of shop operations in which the vise is used were investigated by the Bureau of Standards, sawing, bending and riveting. No vises with swivel bases were examined but 12 new vises of the stationary bottom type were used. They ranged from one having 2 inch jaw and weighing 9 lbs. to the largest with 9 inch jaw and weight of 282 lbs. Each was bolted to a bench of wood 250 lbs. in weight. When a test with one vise was completed it was removed and another bolted in its place. In the sawing tests pieces were cut off from the same steel bar supported in turn by different vises. The same hack-saw frame and kind of blade were employed in all cases and the cut was made ½ inch from the jaws. Comparison was based on the number of strokes necessary to sever the piece. With three sizes of vise this number was 34 and with two others 28, the other seven values fell between these two

extremes. "It is evident that for the conditions used in the sawing tests there is no difference in the efficiency with which filing, sawing, or similar operations are performed in vises of different sizes."

In the bending tests a sledge hammer was supported with its handle uppermost so as to swing about a horizontal axis. Preliminary tests showed that a 12-pound sledge released from a point in its arc 8½ inches above the lowest position would deliver a blow at its lowest point about equivalent to that produced by a 2-pound hammer in the hands of a workman. For each vise three specimens, each from a different bar of steel of standard dimensions, were struck by the swinging sledge and the angles through which the 3 specimens were bent were averaged, care being taken to maintain uniform conditions in all cases. For all sizes of vises the angles were just about the same. Then the effect was tried of releasing the sledge from heights of 3, 5, 7, 9 and 11 inches and letting it strike a specimen once. The angles through the specimens which were bent were found to be proportional to the heights. "The results of the first and second series of bending tests, therefore, show that the size of the vise in which the work is held has no appreciable effect on the efficiency with which material is bent by one blow simulating that from a hand hammer." Then a series was conducted in which the blows were more powerful than the former ones, delivering three times as much energy in the bending of stouter pieces of steel. Seven blows were delivered to each specimen held in each of the 12 vises. "The results of this series show that for heavy bending work requiring the use of a sledge there is a great increase in efficiency up to a certain size, if the work is held in a heavy vise."

In the riveting the sledge rotating about a horizontal axis so that its handle was horizontal when its face struck the middle of the rivet. Five blows were delivered on each rivet, the sledge falling from the same height. The shortening of the specimens was measured. Up to the 5½ inch vise there was a progressive increase in the shortening with increasing weight of vise. Beyond that little change showed itself. Again, tests were carried out with the sledge falling from different heights. "These riveting tests show that up to a certain size the larger the vise the more efficiently the work, such as riveting and chipping, is performed, but that there is no appreciable increase in efficiency if vises larger than 5½-inch (102-pounds) are used." Even stouter rivets were struck 60 blows each. A study of the results confirm the conclusion just quoted.

The displacement of vises to which a force of 50 lbs. was applied was measured. The vertical displacements were small, being only .005, .003, and .004 in. respectively for 2, 5½ and 9 in. vises. The horizontal displacement for the application of 50 lbs. force were, for the same three vises, .04, .022 and .048 in. The estimate is made that in sawing only about .04 per cent. of the total work is expended in deforming the vise and bench. G. F. S.

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